ABSTRACT
LONG, YIXIANG. The Relationships Between Objective and Subjective Evaluations of the Urban Environment: Space Syntax, Cognitive Maps, and Urban Legibility. (Under the direction of Perver K. Baran and Robin Moore.)

To some degree, the urban environment can facilitate/limit one’s orientation, depending on the structure and characteristics of the physical elements of the city. In this regard, Lynch’s concept of legibility has been fundamental in the urban design, planning, architecture, and environmental design fields for a few decades. Lynch argued that a strong legible city could facilitate humans’ orientation in the city. However, urban design research has also criticized Lynch’s work for ignoring the relational characteristics between physical elements of the urban environment. Recent research has suggested that Space Syntax methodology could address the limitations of Lynch’s approach to urban spatial cognition.

The study focuses on exploring: a) the relationships between human cognitive representations and spatial configuration of the urban environment, and b) the effects that different spatial configurations have on legibility of the environment. Two research studies, correlational and experimental, were performed in this study. Two neighborhoods, one relatively intelligible and the other less so, in Changsha, China, were selected for the study areas. The Space Syntax approach was utilized to measure spatial configuration of the neighborhoods. Sketch maps, recognition tests, and interviews were used to measure individuals’ cognitive representations and their perceived legibility of the environment.

Overall, the results of the correlational study indicated that there exists a positive association between cognitive representation and spatial configuration. In particular, the multiple regression analysis showed that global integration is the only significant variable explaining the variation in landmark scores, whereas local syntactical measures (local integration and connectivity) do not play a role in predicting landmark scores. For paths, the
multiple regression analysis showed that local syntactical measures (local integration and connectivity) are the two significant variables explaining the variation in path scores, whereas global integration does not play a role in predicting path scores.

The results from the experimental study indicated that participants’ mean path scores in the sketch maps, the mean scores of scene recognition, and the three mean scores of spatial cognition ability in a more intelligible neighborhood are much higher than those in a less intelligible one. However, no difference in landmark recognition was found between the high and low intelligible neighborhoods. Overall, the findings suggest that the more intelligible an area is, measured by Space Syntax as objective value of spatial configuration, the more legibly it is reflected in a human’s spatial cognition.
BIOGRAPHY

Yixiang Long was born in October 1975 in Yongzhou, P. R. China. He received his Bachelor of Architecture from the Department of Architecture, Hunan University in Changsha, P. R. China. After graduation in 1999, he pursued a Master of Architecture degree at the same university. After earning his master’s degree in 2002, he worked as an intern architect and project architect at an architectural/planning firm in China for two and half years.

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CHAPTER 1: INTRODUCTION

The city has been an object of study for quite a long time. On one hand, humans create cities based on their activities, on the other hand, the city itself facilitates and limits our activities and behavior within it. An important aspect of activities in the city is orientation. Human orientation concerns where one is and how to get where one is going. One’s ability for orientation is extremely important and linked to his/her survival and sanity (Lynch, 1960). The Urban environment, to some degree, can facilitate or limit one’s orientation, depending on the structure and characteristics of the physical elements of the city (Rapoport, 1977; Lynch, 1981; Devlin, 2001).

Lynch (1960) argued that a strong, imageable city could facilitate human orientation. Imageability is the visual quality of the urban environment: the apparent clarity or legibility of the cityscape. Lynch (1960) defined imageability as “the ease with which the physical elements of the urban environment can be recognized and can be organized into a coherent pattern” (p. 9). Based on interviews (including sketch maps) administrated to residents in three American cities, he categorized the residents’ images of the city into five physical elements: paths, landmarks, edges, nodes, and districts. Therefore, he pointed out that an imageable city would be one whose districts or landmarks or pathways are easily identifiable and are easily grouped into a clear and coherent pattern. In turn, this clear and coherent pattern makes the urban environment legible and easily reflected in human’s mind.

Statement of the Problem

Lynch’s earlier pilot work had a far-reaching influence on urban design, planning, architecture, and environmental design. Many designers and researchers have been applying Lynch’s concept of imageability to their professional practice and research work.
However, some scholars and researchers (Jiang, 1998; Kim, 2001; Kim and Penn, 2004) argued that Lynch emphasized the individual physical elements of the urban environment and ignored the relational characteristics between these elements. Actually, this relationship, reflected in people’s minds, is the fundamental root by which humans recognize a built environment, and this is seen as the precursor of humans’ cognitive maps. Subsequently, more detail cognitive maps can be developed (O’Neill, 1991b; Golledge and Stimson, 1997; Jiang, 1998). In addition, in Lynch’s later work, he also addressed the importance of spatial configuration, such as hierarchies, arrangement of paths and location of landmarks, in shaping the strong imageability of the urban environment (1981, 1990).

On the other hand, from a methodological aspect, some studies have pointed out that the way by which Lynch has analyzed the sketch maps disaggregates humans’ cognitive maps. By the disaggregation, one cannot account for the relational properties of urban environments in spite of the admitted importance of continuity and of the interrelationships of elements in evoking a strong image (Kim and Penn, 2004).

**Purpose and Intention of the Study**

Based on the discussion above, this study will focus on investigating the configurational properties of the urban environment and its cognitive representations reflected in human minds. According to Kim and Penn (2004), the existing knowledge gap of the relationship between global configurational aspects and their cognitive representation, and the role of spatial configuration have not been extensively explored. In other words, what is the relationship between human cognitive representations and overall spatial configuration of the urban environment? And how do different spatial configurations of urban environments affect a human’s perceived legibility of the environment?
Significance of the Study

This study is grounded in the conceptual framework of Environment and Behavior (E & B). Studying urban environments and their impact on residents’ spatial cognition is a subarea of E & B studies, which aims to contribute to people’s quality of life and well-being (Lynch, 1984). It also can shed light on the spatial decision-making and behavior of individuals (Livingstone et al., 1994). In practice, the applicability of cognitive studies can inform the future urban design and planning for a better living and working environment (Nasar, 1994).

The significance of this study includes two aspects. First, from a theoretical aspect, it allows us to provide additional empirical evidence to support the argument that spatial configuration of urban environments is a primary root for human beings to shape their cognitive maps. Second, from a methodological viewpoint, it allows us to test if Space Syntax methodology is an effective approach to measure the spatial configuration that will contribute to the legibility of the urban environment. If the relationships between spatial configuration as measured by Space Syntax and perceived legibility are demonstrated, designers can utilize Space Syntax methodology to understand and evaluate alternative site designs and plans for their spatial configuration quality, which ultimately could contribute to improve legibility.
CHAPTER 2: LITERATURE REVIEW

This chapter will survey and analyze the literature from three fields — spatial cognition, legibility and wayfinding, and Space Syntax. In the first part, it will discuss what spatial cognition is, theories, methodologies and findings, and how they raise research questions/hypotheses from different perspectives to study spatial cognition. The second part of this chapter will focus on the legibility of environment and its role in the wayfinding process. The third part will discuss the theory and methodology of Space Syntax, and give an overview of studies on spatial configuration and spatial cognition that have employed Space Syntax approach. Finally, conclusions from the literature review will be drawn to initiate the conceptual framework of this specific study.

2.1 SPATIAL COGNITION

Hart and Moore (1973) defined spatial cognition as “the knowledge and internal or cognitive representations of the structure, entities, and relations of space; in other words, the internalized reflection and reconstruction of space in thoughts” (p. 248). In general, spatial cognition is the human understanding and perception of geographic space. Geographic space is large-scale space. It is “a space whose structure is at a significantly larger scale than the observations available at an instance. Thus, to learn the large-scale structure of space, the traveler must necessarily build a cognitive map of the environment by integrating observations over extended periods of time, inferring spatial structure from perceptions and effects of actions” (Kuipers and Levit, 1990; p. 231). Thus, geographic space differentiates from small scale space or ‘table-top’ space, in which objects are thought of being manipulable or explorable from a single point of view. The urban environment can be seen as a kind of geographic space either at the architectural scale or city scale.
In practice, researchers use another term, *environmental cognition*, to indicate the human ability to image and think about the world around us. Bell et al. (2001) define *environmental cognition* as the following:

> We acquire facts and opinions about the world around us, and we remember emotional reactions to environments from experience. Presumably, we can use this mental representation of the physical environment to make plans, to understand the terrain around us, or solve problems involving an environmental context—finding a dry cleaning establishment, for example. In general, researchers refer to this ability to image and think about the spatial world as environmental cognition. (Bell et al., 2001, p. 57)

Comparing these terms points to the fact that *environmental cognition* is broader than *spatial cognition*, since it not only includes the human ability to understand and reconstruct environments, but also the ability to make plans and solve problems, such as route choice and wayfinding. On the other hand, spatial cognition specifically refers to the environments beyond a human’s immediate comprehension, such as an urban environment and complex buildings, while environmental cognition includes both.

In cognitive studies, quite often researchers use another term, *environmental perception*, instead of *environmental cognition* or *recognition*, to describe the human’s ability to comprehend, interpret, and evaluate the physical world surrounding us. While these two terms have been used in a confusing variety of contexts, there is a difference between them. According to Bell et al. (2001), the term *perception* involves experiences and memory, which imply that cognitive processes are involved. In addition to cognitive process, our feelings about the environment influence our perception of it, and our perceptions influence our feelings. Thus, it includes both assessment of what is in a scene and an evaluation of the good and bad elements. In contrast, the recognition focuses on perception as a process for gathering information about the world and as a resource of affective responses and associations.
On the other hand, according to Passini (1984), *environmental perception* is more related to ‘sensory information’, whereas *environment cognition or recognition* is considered ‘memory information’. It is understood that sensory information also involves memory and that memory information once went through the process of being directly perceived. However, the important difference between the two terms is that at a given moment, memory information can be obtained without or independent of sensory inputs from the setting, while sensory information cannot (p. 60).

### 2.1.1 Cognitive Maps: Process, Development, and Models

#### 2.1.1.1 The Process of Cognitive Maps

How human beings comprehend real-world environments is a major question within environment-behavior studies and also has been extensively discussed by environmental psychologists, urban planners, architects, environmental designers, and geographers. As early as 1913, Trowbridge studied how individuals orient in geographic space. However, scant human research was conducted until the early 1960s. An exception was the important animal work initiated during this period by Tolman (1948) in his classic studies of place learning that challenged strict Stimulus-Response learning theory (Evans, 1980). Tolman, conducting a series of ingenious experiments in which a rat was trained to find food by following a single roundabout pathway, found that when given the opportunity to go directly to the food, the animal took it. It went directly to the place where the food was, rather than following the original pathway. The animal, according to Tolman's interpretation, gradually developed a “picture” of its environment that was later used to find the goal. The picture was called a *cognitive map*. In fact, real-world settings differ in stimulus arrays used in most experimental studies of cognition. In a real-world setting, the observer is an interactive part of the environment, not a passive observer of stimulus objects. The environment surrounds
the observers and is viewed from multiple vantage points as it is explored. Further, as Ittelson stated (1973), information in real-world settings is not isolated, nonsensical material. Instead, the information has meaning with the context of the setting.

Although controversy still exists regarding place versus cue response theories of learning, the term cognitive map has remained as a general term of the cognitive process involved in the acquisition, representation, and processing of information about actual physical settings (Downs and Stea, 1973; Moore, 1979; Moore and Golledge, 1976; Evans, 1980). In reality, researchers in different fields may use different terms such as mental maps, mental image, and mental pictures, which have the same meaning as cognitive maps (Downs and Stea, 1973).

The term ‘cognitive map’ is widely used in a number of disciplines such as environmental psychology, social psychology, anthropology, geography, cognitive studies, city planning, urban design, and architecture. Cognitive maps are mental constructs that encompass all the internal processes that enable people to acquire and manipulate information about the nature of their spatial environment (Downs and Stea, 1973). They are incomplete, segmented and mentally distorted internal representations of the environment. They are constantly being updated and so at any one instance it is merely a snapshot of the contemporary state of physical knowledge. “Cognitive maps are the internal information structure that people use to represent information about everyday physical environment” (Garling, Book, and Lindberg, 1984, p. 98). According to cognitive psychology, a mental image does not seem to be a “picture in the head.” It differs from a picture in that it is not precise, it can be distorted, and it is segmented into meaningful pieces (Anderson, 1995). Additionally, a cognitive map is also a “compact orderly collection of knowledge. It contains more information than one can generally conceive at once, thus permitting one to anticipate, to react, to consider next possible events” (Kaplan and Kaplan, 1982, p. 63). Furthermore, it
provides a satisfactory basis for decisions even when a lot of information is missing. Finally, cognitive maps are considered to be essential components in the adaptive process of spatial decision-making. Cognitive maps are used to understand and know the environment, predicate the environment, and guide spatial behavior (such as wayfinding) in the environment (Kitchin, 1994).

Evans (1980) argued that cognitive maps can be distinguished from other cognitive representations of information, such as signs, maps, and icons. First, cognitive maps primarily represent spatial relationships among areas. They represent relative distance, orientation, and cardinal directions of different parts. Stea (1969) has indicated that cognitive maps also reflect information about the hierarchical arrangement of points in space, with respect to relative distance and size. They also contain information about the degree of interconnectedness among points in the geographic environment. Second, the representation, although not strictly cartographic, experientially contains some maplike qualities. A good cognitive map facilitates movement through the actual physical setting represented by the cognitive representations of that space.

Experiments in cognitive psychology show that subjects’ memory appears to have the hierarchical structure associated with spatial images. For example, if an individual draws a mental map of the map of the United States, it is probably divided into regions, and subdivided into states. Then, cities are presumably pinpointed within the states. On the other hand, the map probably contains certain systematic distortions and errors. This means that memories may be stored according to hierarchical principles, but there remain some interconnections between areas that cut across this hierarchical structure. This reliance on “higher order” information leads to errors (Anderson, 1995; Stevens and Coupe, 1978). Storing information hierarchically can make humans acquire spatial information quickly and minimize memory loss (Bell et al., 2001).
2.1.1.2 The Development of Cognitive Maps

How are cognitive maps developed in the human mind? According to Hag (2001), there are two ways to shape human cognitive maps. One is direct communication with the physical environment. Another is indirect representations of it by being exposed to various media verbally and orally, such as direction maps, pictures, or moving images. In this regard, individuals receive information directly/indirectly from complex, constantly changing, and unpredictable environment where he/his lives. Based on this kind of communication with the environment, he/she begins to accumulate information to shape a mental structure that contains a representation of the environment. More importantly, cognitive maps are not still images, but constantly being updated by his/her continued interaction with the environment.

The development of cognitive mapping is a means of structuring, making sense of, and dealing with the complexities of environments that are external to the mind (Golledge, 1987). Therefore, the development of the cognitive maps is primarily built upon both environmental and individual factors. Obviously, familiarity with the environment is important to human cognitive mapping development. For example, as a person gets to know an environment more, he/she will generally have a better cognitive map of it. On the other hand, individual characteristics and abilities can also play an important role in this process. Some people seem to find the direction and destination almost effortlessly, while others are lost frequently. However, the individual ability and competence is outside the discussion of this study.

Most studies in the development of spatial cognition in humans have roots in the work of Piaget and his colleagues (Piaget and Inhelder, 1967). Perhaps their most basic finding is the fact that representations of space are primarily built up by acting-in-space and not by perception-in-space. In other words, individuals develop their cognitive maps by moving within a space. Further, Piaget and his colleagues discovered that there exist three kinds of
spatial relations that shape human spatial cognition: topological, projective, and euclidian. Topological relations are the relations of places and their association with one another. Projective relations are the spatial relations of objects that depend on a particular perspective or point of view. Euclidian relations mean that spatial objects are represented with precise coordinates along objects edges or outlines. Based on work with children, Piaget and Inhelder indicated that the knowledge of basic geometric properties of space is learned sequentially: first, an intuitive understanding is attained based on direct experiences; second, some spatial thoughts allow systematic reversible operations; and finally, spatial thoughts are developed so that they can be disengaged from action.

2.1.1.3 The Models of Cognitive Representations

Studies in cognitive psychology show that sensory memories merely store sensory representations for a few seconds at most (short-term memory). Beyond the first few seconds, information must be transformed, or encoded, into more permanent representations (long-term memory). Some of these permanent representations tend to preserve much of the structure of the original perceptual experience. Others, however, are quite abstracted from the perceptual details and encode the meaning of the experience (Anderson, 1995).

Generally speaking, two relatively distinct models in cognitive psychology propose how information is cognitively represented (Evans, 1980). The concept of a proposition is borrowed from logic and linguistics. Propositional models of cognitive representation state that information is stored in lists or associated networks based on abstract representations of meaning (Anderson and Bower, 1973; Pylyshyn, 1973). “A proposition is a configuration of elements which is structured according to rules of formation, and has a truth value.” (Anderson and Bower, 1973, p. 3). The environment is represented as a number of concepts
or ideas, each of which is connected to other concepts by testable associations such as color, name, sounds, and height. Closely related to the propositional view is the concept of schemata. A schema is conceptualized as a mental structure, which contains general expectations and knowledge of the world (Augoustinos and Walker, 1995). As a mental structure, schemas contain abstract and general knowledge about a particular area. For example, in cognitive representations of large cities, people have to schematize drastically if they are to gain any overall comprehension of the urban structure. They extract dominant reference points, a group of districts, or a single line of movement on which their recollections hang. These simple patterns and networks are also the common stereotypes of utopian city design (Evans, 1980). Therefore, the type of schematic structure that helps humans search for and comprehend environmental information is critical to location and orientation decisions (Kaplan, 1973; Neisser, 1976; Stea, 1969). Also it gives people some sense of predication and control of the urban environments.

A second perspective on cognitive representations of information is the analogical view, which states that mental representations maintain some rough, isomorphic correspondence to the actual physical structure of the information in the world --- a one to one relationship between representation and reality (meaning the mental map is an analogy of the real world) (Kosslyn, 1975; Shepard, 1975). The cognitive map roughly corresponds point for point to the physical environment, almost as if there is a file of slide photographs of the environment stored in the brain. The correspondence between the internal, imaginable construct and the external object is considered functional, not literal. The reconstruction of the external array by the internal representation reexcites neural processes that are functionally equivalent to those mental processes elicited directly by the external array (Cornoldi and McDaniel, 1991; Kosslyn, 1980, 1983).

These two opposing views have been modified to the position that cognitive representations
may code information in the form of propositions but can manipulate it analogically (Kosslyn and Pomerantz, 1977). The view here is that knowledge about the content and location of places in the geographic environment is stored in both prepositional and analogical form. Most information in cognitive maps such as abstract labeling of environmental elements (path, landmarks, etc) and cardinal directions, are stored in memory through propositions and are affected by previous knowledge of settings in general. Under this proportional network, some information, such as the relative spatial positions of objects in settings, may be processed analogically, just like constructing analogical image that has many of the qualities of a photograph. This image may then be used, rather than the prepositional network, to solve spatial cognition problems, such as wayfinding.

2.1.2 Physical Environment and Cognitive Representations

*Physical environment* refers to all natural features of geography, climate, and man-made features, which limit and facilitate behavior, and the “resource” of the environment (Lawton, 1970). In this study, the physical environment specifically refers to the man-made/built urban environment.

Cognitive maps are an internal reflection of the physical environment. To store the urban environment quickly and efficiently in memory, humans need to abstract the physical environment into cognitive representations. Certain environmental elements, which are more “imageable” than others, are easily stored in the human mind. As early as the 1960s, from interviewing and studying sketch maps of 36 residents in three American cities, Kevin Lynch suggested five key “imageable” elements that comprise cognitive maps of urban settings: path, nodes (path intersections), landmarks, district, and edges (boundaries). After Lynch’s pilot study, many studies (Appleyard, 1969, 1970; de Jonge, 1962; Francescato and Mebane, 1973; Gulick, 1963) have confirmed the results, but varying in importance of elements (Table
1. Landmarks are eternal points of references for the observers that posses some distinctive form that contrasts with background information. Examples are tall buildings, buildings with distinctive colors or large bulk, and distinctive structures (i.e. Washington Monument in Washington D.C., Bell Tower on NCSU campus).

2. Districts are medium-sized subsections of the city that one may enter and feel “inside of”, such as a business center, campus, or residential neighborhood.

3. Paths are the channels along which the observer customarily, occasionally, or potentially moves. They may be streets, walkways, transit lines, canals, and railroads.

4. Edges are linear elements not used or considered as paths by observers. They are the boundaries between two phases and are linear breaks in continuity: shores, railroad cut, edges of development, and walls.

5. Nodes are points, the strategic spots in a city into which an observer can enter, and that are the intensive foci to and from which he/she is travels. They may be primarily junctions, places of a break in transportation, a crossing or convergence of paths, or moments of shift from one structure to another. Examples are a traffic square, park, civic square, etc.

These cognitive representations are a subjective evaluation of the urban environment. They are extremely difficult to describe objectively. Their characteristics are hard to formulate and they vary for different persons due to each person’s varying cognitive systems. For example, Appleyard (1970) had proposed the size of the building to be an important characteristic of a landmark, while Evans (1980) had suggested color as an important characteristic. Nevertheless, Appleyard (1969) synthesized the characteristics of urban elements that make them recognizable as landmarks into five major categories. The categories include: use (function), location, historical meaning, physical characteristics and maintenance. Among them, building location is one of the most important characteristics for landmark buildings.
Urban environments are usually recognized and remembered because of some characteristics of physical elements, such as color or shape of the building, width, or pavement of road, and so on. Such properties can be understood by being within a space itself. On the other hand, another property of an urban environment is not acquired by staying within one space, but by moving from one space to the other. The properties acquired by individuals’ movements within spaces comprise the relationships that each space connects with all others. These properties are expected to be an important component of the cognitive maps, since cognitive maps are developed through movement (Piaget and Inhelder, 1967). In this regard, the former is termed as *discrete* properties (discrete elements) and the latter as *relational* properties (relational elements) (Haq, 2001). Hillier (1999) regards these two as local and non-local properties of the urban environment. The non-local relational properties raise the issue of spatial configuration and the distinction between metric and topological properties. The differences between metric and topological properties will be discussed in the next section.
<table>
<thead>
<tr>
<th>Year</th>
<th>City</th>
<th>Interview Sample</th>
<th>Important Elements</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>K. Lynch (1960)</td>
<td>Boston, Jersey City, Los Angeles (United States)</td>
<td>60 (Professional, managerial)</td>
<td>● ● ● ○ ●</td>
<td></td>
</tr>
<tr>
<td>D. de Jonge (1962)</td>
<td>Amsterdam, The Hague, Rotterdam (Netherlands)</td>
<td>72 (Wives of white-collar workers)</td>
<td>● ● ● ○ ○</td>
<td></td>
</tr>
<tr>
<td>J. Gulick (1963)</td>
<td>Tripoli (Lebanon)</td>
<td>35 (students, upper middle class)</td>
<td>○ ○ ●</td>
<td></td>
</tr>
<tr>
<td>H. Klein (1967)</td>
<td>Karlsruhe (Germany)</td>
<td>1118 (Residents)</td>
<td>● ● ○</td>
<td></td>
</tr>
<tr>
<td>T. F. Saarinen (1969)</td>
<td>Chicago (United states)</td>
<td>72 (students, workers)</td>
<td>● ● ● ○ ●</td>
<td></td>
</tr>
<tr>
<td>D. Appleyard (1969)</td>
<td>Ciudad Guayana (Venezuela)</td>
<td>320 (Residents from selected settlements)</td>
<td>○ ●</td>
<td></td>
</tr>
<tr>
<td>D. Stea and D. Wood (1970)</td>
<td>Mexico City, Puebla, Guanajuato, San Cristobal las Casas (Mexico)</td>
<td>769 (Residents, students)</td>
<td>● ● ● ○</td>
<td></td>
</tr>
<tr>
<td>D. Francesco and W. Mebane (1973)</td>
<td>Milan and Rome (Italy)</td>
<td>183 (residents)</td>
<td>● ● ○ ●</td>
<td></td>
</tr>
<tr>
<td>X. Yan (1990)</td>
<td>Beijing (China)</td>
<td>432 (residents, professional)</td>
<td>● ○ ● ● ● ●</td>
<td></td>
</tr>
<tr>
<td>K. Lynch (1990)</td>
<td>Theoretical arguments</td>
<td></td>
<td>● ● ●</td>
<td></td>
</tr>
</tbody>
</table>

Notes: ○ Important element ● Very important element
2.1.2.1 Topological and Metric Relations

Topological relations are the relations of places and their association with one another. They indicate the connections between spaces, which gives people a sense of possibility of travel from one location to another, and what spaces one would pass through if he/she wants to reach a distant space. On the other hand, metric relations indicate the direction and the distance between spaces. Metric relations contain information that allows people to understand the distance and the direction of a place where they are located with respect to another place they would go.

Both metric and topological information are integral to the cognitive map. However, topological information is probably acquired first and is a precursor to a more complete cognitive map (Evans, 1980). As we learn about an environment, the mental connections between spaces strengthen and accumulate, thus a simple “strip map” representation develops into an integrated spatial overview, or “survey map” (Hart and More, 1973).

The topological information (strip map) plays an important role in orientation and wayfinding. For instance, a wayfinding act based on metric knowledge would have no information about travel paths or how to get to the destination point. Therefore, one may have a great deal of trouble finding the destination since dead ends or blockages would not be represented. For wayfinding or orientation at the urban and building scale, it is important to know the connections between spaces because this information is necessary for selecting a route from start to end successfully (O'Neil, 1991b). Also, this topological information is necessary for giving wayfinding directions to a stranger (Hillier, 1999).

On the other hand, when moving around the urban environment, people tend to choose a route with fewer turns, rather than more turns, while the metric distance between A and B is
the same (Figure 1). Hillier and Iida (2005) indicated that human beings read the urban network in geometrical and topological terms, rather than metric terms. Human beings’ movements are an economic behavior. Thus they attempt to find the shortest way to minimize distance. However, their concept of distance is shaped more by the geometric and topological properties of the network than by an ability to calculate metric distance.

![Figure 1: Topological and Metric Relations Between A and B.](image)

As knowledge of the connections between spaces is gradually developed, a sense of spatial configuration is attained. Much research indicates that such topological information is acquired first and is a skeleton of a more detailed cognitive map (Evan, 1980; Kuipers, 1983). It allows humans to shape a usable representation of the environment by integrating many small and incomplete pieces or views (Kaplan and Kaplan, 1982, Haq, 2001).

Studies (Hillier, 1996; Haq, 2001) have suggested that various levels of topological relationships in human cognitive maps exist. For example, understanding simple connectivity of any space or a route to immediate ones comprises basic topological knowledge, which is considered as a ‘local’ level understanding. On the other hand, a global sense that contains information on how all the spaces in a system are connected to each other comprises a high-level topological understanding of that configuration. This multi-level
aspect of topological relationships has great influence on human wayfinding behavior. Few studies (Peponis et al., 1990; Hag, 1999, 2001) have indicated that in exploratory navigation, the local information, such as connectivities, is more influential. However, when people become familiar with the environment, they gradually acquire a sense of global relationships of spaces and the cues for wayfinding performance shift from local information to global information.

The next two sections will discuss empirical studies about the physical elements (discrete elements), spatial configuration, and spatial cognition.

2.1.2.2 Physical Elements and Spatial Cognition

Many studies suggest that distinctive landmarks, particularly when placed at decision points, affect cognitive strategies for wayfinding (Lindberg, 1984; Jones, 1972; Heft, 1979). Other studies indicate that building location may affect recall. Buildings proximate to important road intersections, visible from primary traffic arterials (Appleyard, 1970, 1976), or positioned close to a road in a scale model (Herman and Siegel, 1978) are more frequently recalled or more accurately relocated respectively. Similarly, Lynch (1960) suggested that landmarks, particularly when aligned with major pathways, would facilitate urban image formation by helping individuals to recognize their positions in geographic space relative to destination or starting points.

Evans et al. (1984) investigated how pathway grid configuration and landmark placement affect humans' environmental cognition. They used environmental simulation to let each of the 128 respondents view a film that showed two different routes (one through grid and one through nongrid layouts). Each route consisted of two different landmark conditions (i.e., internal and external). Internal landmarks are those placed within the immediate field of view
(e.g. on a street corner). External landmarks are not in the immediate field of view but in the distant line of sight (e.g., tall building on the horizon). The authors let each respondent recognize the items in the films, draw the route maps, and put photographs printed directly from the films in sequential order. The results showed that landmarks and grid configuration facilitated geographic knowledge. Grid structure enhanced route accuracy, but had little influence on memory for actual place locations or spatial order. Landmarks on the other hand did not influence route learning much, but improved comprehension of place locations. Moreover, regarding internal and external landmarks, while none of the differences between internal and external landmarks were statistically significant, there was a consistent trend that showed that internal landmarks were more helpful in recognition than external landmarks. However, the researchers suggested that relative importance of these two types of landmarks would need more investigation in real space. On the other hand, there were many other physical components for learning in real world settings that were suggested by Lynch, Appleyard, the Kaplans and others that need further empirical investigations, for example, the importance of nodes, edges, districts, and so on.

Appleyard, Lynch, and Myer (1964) investigated what aspects of settings are remembered or used when traveling. They asked subjects to make rapid sketches depicting what they perceived as they travel over designated road sectors. Subjects also recalled features along the route. Of the respondents, 20-25% drew the road ahead, 10-15% drew objects overhead and large objects at the edge of the road, 5-10% drew distant landmarks, guide rails, and other road edges details, and 2.5-5% drew signs, layouts, traffic, and hills.

In 1975, developmental psychologists Siegel and White studied the sequence in which environmental elements are acquired. They proposed that landmarks are acquired first, followed by knowledge of routes. Survey or configurational knowledge develops last (Golledge, 1987). Landmark knowledge is familiarization of an element or a place in the
environment without knowledge of locations relative to others. Route knowledge is the knowledge of how to go from one location to another without a definite sense of their relative positions. The third and most comprehensive is the survey type of knowledge. This is the knowledge of relative locations of environmental objects (landmarks) and their interconnectedness.

In another study, Lindberg and Gårling (1983) found evidence that paths were learned before or at least along with landmarks. The authors argued that the base of environmental knowledge is the connections between spaces. As people gradually learn about environments, these mental connections between places strengthen and accumulate. In this manner, a simple ‘strip map’ representation is developed into an integrated spatial cognition that is also known as a survey map. Similarly, Peponis, Zimiring, and Choi (1990) investigated spatial cognition and wayfinding in a complex hospital. They found that the path is a very important element in wayfinding performance when it must be used to finding a specific destination. Traveling around the paths gives people the understanding of the overall spatial configuration of a building.

While there is controversy with respect to the sequence in which environmental elements are learned, the survey knowledge of environment --- the knowledge of relative locations of environment objects and relationships between spaces --- is the final result of cognitive maps after repeated human movement.

2.1.2.3 Spatial Configuration and Spatial Cognition

The previous literature review on physical elements and spatial configuration suggests that configurational aspects of the environment have significant cognitive consequences. Hillier (1996) has argued that spatial configuration may place constraints on spatial experiences
because it encourages or impedes aspects of human activity through spatial cognition and subsequent behavior. He has defined spatial configuration simply as “spatial relationship taking into account other relations” (p. 1). Similarly, Peponis et al. (1990, p. 556) defined configuration as "the way in which spaces are related to one another, not only pair-wise but also with respect to the overall pattern that they constitute. In other words, configuration is about the overall pattern that emerges from pair-wise connections rather than elements or single connections taken by themselves.”

Urban planners have stressed the importance of spatial configuration in spatial cognition (Appleyard, 1976; Lynch, 1960), with particular emphasis on regular, well-defined path systems. Lynch also addressed the grid and hierarchy in his many writings, while his main emphasis in his 1960 book is the five physical elements. Although he was not a cognitive psychologist, he recognized the importance of relationship between spatial configuration and mental structure. One of the intersections between cognition and urban planning is the emphasis on hierarchies. “The idea of hierarchy is persistent in planning. It seems to be a natural way of ordering things, although this may be a consequence of the way in which our minds work” (Lynch, 1981, p. 389).

Some empirical data support these concerns. De Jonge (1962) found that residents of cities with more regular (i.e., linear, parallel, and perpendicular configuration) street grid patterns drew more complete, accurate city maps. Tzamir (1975, see Evans, 1980) has extended this earlier work by varying the similarity of pathway distances and pathway angles of intersect in a scale model. Subjects viewed videotapes made by a camera that moved through the model, simulating a drive around the city, and were then asked to draw the model from memory. For this task they were provided lists of path and node names in the model. Incorrect or absent path linkages or basic topological distortions of path configurations were scored as structural distortions. Consistent with Lynch’s hypothesis, the model with the least
variability (least turns) in the path and angles of intersection had the fewest structural errors.

Zannaras (1976) explored the effects of city structure on cognitive representations of environment. She asked subjects to trace routes from the outskirts to the central core of three cities on either models or maps. Each city represented one of the three major urban organization patterns: concentric zone, sector zone, and mixed concentric/sector zone. The major dependent variable was ratings of the relative importance of environmental features in wayfinding. The study found that traffic features (railroad crossings, traffic lights) were most important in the concentric zone city structure, and land-use cues (functions of buildings) were most predominant for the other zonal organizations. This study suggested that people might use different orientation cues to navigate in concentrically arranged cities than in cities with a sector structure.

In another study, subjects viewed sequential slides that depicted a drive down a novel but typical urban street in Los Angeles (Jones, 1972). At appropriate intervals five cross streets were shown on a screen $90^\circ$ to the left. At each intersection subjects had to choose whether to continue straight ahead or make a left turn and proceed down the side street that was then simulated. The subject's task was to reach and enter a freeway entrance. The correct solution of the problem entailed continued travel on the main road, that is, no branching off to the left. Thus the correct solution was unfortunately confounded with continued progress on the road and no exploratory behavior. The subjects' behavior was monitored based on three conditions: no cues removed from slides, high-rise buildings removed, high-rise buildings and free structures (ramps, bridges, abutments) removed. Analysis revealed no differences for the first two conditions, but for the third condition (both cues removed) subjects made substantially more incorrect decisions to branch off. Based on these findings, the author tentatively concluded that the relations between cues were more important than distance high-rise buildings (distant landmarks) in making path choice decisions in a novel
In a later study, O’Neill (1991b) investigated the relationship between floor plan, spatial cognition, and wayfinding performance. He measured layout complexity as the average number of topological connections per choice point in a floor plan. He called this ‘inter-Connection Density’ (ICD). This was used as an independent measure to test both wayfinding and environmental cognition. By using sketch mapping, photograph sorting (recognition test), and actual wayfinding tasks he found that as topological floor plan complexity increases, people tend to experience difficulty in drawing cognitive maps and wayfinding.

Recently, Yun and Kim (2007) investigated the interrelationship between spatial cognition and configuration, and the effects of turns in path (depth) and metric distance in forming spatial cognition by using Space Syntax. They found that there is a strong interrelationship between the syntactic properties and spatial cognition as indicated in the cognitive map. In addition, both depth and distance have a large influence on spatial cognition. However, a comparison of the influence of depth and that of distance showed that depth has more influence than distance on spatial cognition.

Based on the discussion above, it is noted that the configurational properties of the environment itself are important variables in acquiring environmental knowledge. In spite of their importance in cognitive studies, empirical research studying the role of spatial configurational properties in human spatial cognition has been limited (Weisman, 1979; Peponis et al, 1990). One reason for this is the limitation in the methods and techniques available to objectively measure environments from the point of view of recognition. However, current development in Space Syntax has led to a computer based analytical method in studying configurational properties of an entire urban environment.
2.1.2.4 Personal Experiences and Spatial Cognition

A considerable body of research in spatial cognition has investigated individual differences in acquiring spatial knowledge. Most of the research has focused on gender differences, class/culture, familiarity, and commutativity/associativity.

Most cognition mapping research has found no gender differences in environmental knowledge based on sketch maps (Francescato and Mebanem 1973; Maurer and Baxter, 1972). However, Orleans and Schmidt (1972) found that men constructed sketch maps using provided base map coordinates, whereas women used their home as a fixed referent system and largely ignored the provided abstract coordinates. Appleyard (1976) also found that men drew slightly more accurate and extensive city maps than women did, which he attributed to greater travel and exposure in the city by men. Overall, most research on a gender difference in spatial cognition has found few differences until adolescence, when a slight male advantage emerges (Maccoby and Jacklin, 1974). In addition, some studies investigated the effects of individual’s spatial ability on his/her work performance. It was found that people who have high spatial ability test scores (one type of intelligence) tend to succeed in engineering, mathematics, architecture, and other fields of the study (Anderson, 1995). The results implied that some people might have inborn talent in developing a better spatial cognition of the urban environment than that of the others.

Much of the research in class/culture area has focused on class differences in spatial cognition, although a few cross-cultural investigations have been conducted. Orleans (1973) discovered that an upper class, professional group drew much broader, more accurate maps of Los Angeles than both middle and lower class respondents, whose maps were restricted and accurate only for their immediate environment. Orleans argued that these differences emanated from the greater breadth of social contacts that the upper class had. He found that
the upper class subjects were significantly more likely to have close friends outside of their immediate neighborhood than subjects in the other groups. Appleyard (1976) found the opposite result in his research in Ciudad Guayana, Venezuela. Low-class people had more complex maps that indicated more detailed knowledge of the city than did the upper class, although the latter group more accurately coordinated the interrelationships among distinctive districts of the city. Appleyard suggested that the greater knowledge of lower class was explained by their daily travel experiences. The wealthy lived near the major places of employment and rarely traveled to lower-class areas of the city. The poor traveled across town each day to the factories, offices, and homes of the wealthy, in which they worked. Thus the poor gained wider city exposure.

Several researchers have examined the effects of setting familiarity on spatial cognition. Setting familiarity is the connection/interaction or amount of exposure between an individual and the urban environment that they use. There are two competing models of how people learn a new setting. One position argues that individuals initially rely on paths and districts to orient themselves in a novel environment. Later, when they are more familiar with the setting, they rely primary on landmarks for orientation (Appleyard, 1970, 1976; Lynch, 1960). Conversely, both Hart and Moore (1973) and Siegel and White (1975) theorized that environmental learning is primarily landmark based, with path structures elaborated subsequently within original anchor, landmark points.

Principles of commutativity and associativity are also important criteria in individual’s environmental knowledge. Commutativity and associativity mean an inhabitant’s daily commuting experiences, setting function (use), and meaning, which he/she individually associates with the environments. Research indicates that the relative locations of home, work, schools, and shopping areas strongly affect the extent of an individual’s knowledge of the immediate geographic environment (Horton and Reynolds, 1971). Similarly, cognitive
representations of downtown urban areas differ in their overall distribution of detail as a roughly linear function of distance from where individuals work or live with respect to the downtown (Lynch, 1977). Finally, Holahan (1978) demonstrated that students draw more complete, detailed maps of campus areas they actually use more often. Displacement of the perceived center of campus was also skewed toward a student’s usual entry point onto campus.

There is also evidence that recognition memory for components of a city is related to actual experience as well as to general residential history. Studies indicate that the longer a person lives in a city, the greater the number of photographs of the city they could identify and locate (Evans, 1980). In the mean time, the elements of a city most frequently recalled and recognized are located in the heart or center of the city (Banerjee, 1971, see Evans, 1980; Milgram et al., 1972). In addition to the amount of experience, the type of experience in the setting may be important. Appleyard (1976) found significant travel mode effects when comparing bus and automobile users, which in turn was correlated to class. Bus riders generally saw more of the city, especially off-the-road features, but had a poorer sense of the overall configuration of the city. Similar data have been reported by Beck and Wood (1976).

2.1.3 Methodological Issues in Studying Cognitive Representations

The essential methodological problem faced by investigators of cognitive representations of the real-world environment is how to externalize the individual’s mental map of the environment. Researchers in environmental cognition have depended largely on individuals’ hand-drawn sketch maps of their immediate surroundings as indicators of the cognitive process invoked in the perception and comprehension of the everyday environment. The use of sketch maps as a source of data raises several questions. For example, do individual
differences in drawing ability seriously confound sketch map output? Rothwell (1976) found a small but significant correlation ($r=0.14$) between adults’ graphic skills and the accuracy of home floor plan drawings. From this finding, it is inferred that adults’ graphic abilities may only have a slight affect on sketch map productions.

The process of sketch mapping and the map itself have been used as research tools to measure how people perceive and recognize their built environments and how people act in them. It has long appeared to be a useful instrument for recovering information about the way we represent the environment to ourselves. Kim and Penn (2004) stated that although sketch maps are generally incomplete, distorted, and employed with mixed metric or nonmetric modes of representation, they provide data, such as the number of features; the mix of point, line, and area features; and the topological relations of elements; including the sequences of cues along routes or the sequence of segments and turns along routes.

Evans (1980) stated that parameters of the drawing task itself may be problematic as well. The issue of scale is pertinent. Artifactual variables that could have an impact on scale include the size of the drawing surface and the order in which things are drawn. Initially drawn elements may have substantial effects in the relative size and position of subsequent elements. The more elements one has put down in a drawing, the fewer the degrees of freedom that remain to maintain size and distance scale. Research on young children’s drawings of simple objects (typical human figures) has shown that initial picture units impose restrictions on the size and relative position of subsequent picture components (Goodnow, 1977).

Beck and Wood (1976), in a review of research in cognitive mapping, have also suggested that researchers use varying procedures to elicit cognitive maps. They have suggested that symbolization (map-drawing) and verbalization (descriptive procedures) may be combined
to measure a person’s spatial cognition. Besides free map drawing and verbalization, other measurement techniques have also been used based on the research purposes, such as free recall, distance estimation, recognition test, and map labeling (Evans, 1980).

Yeung and Savage (1996) gave respondents a map of the vicinity of Orchard Road without road names and let them label the road names, important buildings as landmarks, and squares as nodes to investigate residents’ imageability of the city of Singapore. Another study (Haq, 2001; Haq and Girotto, 2003) let respondents identify the locations in the buildings, where they had just traveled to investigate the influence of spatial cognition on wayfinding performance.

Cohen (1980) has suggested the types of cognitive mapping tasks used to externalize subjects’ knowledge of their environment were found to be significant factors in assessing the subjects’ cognitive maps. If an investigator is primarily interested in the elements of an environment a subject has stored in memory, then recognition and probe recall (association) tasks will be sufficient to assess this level of knowledge. But, if the primary interest is to understand the relationships between environmental elements, then the free recall procedures of maps (sketch maps) and written descriptions should be used (Cohen, 1980). These tasks reveal more of the underlying structure of cognitive maps through usage of elements and relationships between elements they elicit.

Based on the previous literature review on spatial cognition and physical environment, if the methods for environmental cognition are chronologically considered, then an interesting pattern begins to appear. As shown in Table 2, whereas the earlier studies primarily dealt with physical elements (discrete properties), the work done after the late 1970s show a concern regarding the spatial configuration (relational properties) as an important environmental property However, at that time, there seems to be a lack of appropriate tools
and techniques to allow these properties to be defined or measured. Many of the tools and techniques used in the 1970s were inter-subjective or qualitative methods (Weisman, 1981). Although useful to prove theoretical arguments, those studies could not objectively describe or measure relational properties (Haq, 2001). On the other hand, as we can see in Table 2, prior to the 1990s most studies on environmental cognition were mainly conducted by using environmental simulation and models in a highly controlled lab setting. Although laboratory research has the advantage of controlling exogenous variables, it tends to miscalculate a human’s true competence of acquiring spatial knowledge and wayfinding performance (Garling et. al, 1986). A less controlled naturalistic setting allows a human to show more regular behavior and represents the complex world as an interacting process at most. This may be one of the reasons why after the 1990s most of research in environmental cognition was conducted in a naturalistic setting.

In the 1990s, the field saw a trend of utilizing Space Syntax combined with the other alternative methods to investigate such relational properties. However, most of the studies were conducted in building environments. Little research was conducted to examine the relationships between cognitive representations and spatial configuration in an urban environment by using Space Syntax. In the meantime, few studies attempted to explore the relationships between physical elements and spatial configuration (Kim and Penn, 2004).

Table 2: Methods Used in Environmental Cognition.

<table>
<thead>
<tr>
<th>Yr</th>
<th>Author</th>
<th>Physical Elements</th>
<th>Spatial Configuration</th>
<th>Spatial Behavior</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>Lynch</td>
<td>Paths, nodes,</td>
<td></td>
<td></td>
<td>Sketch maps, interview</td>
</tr>
<tr>
<td></td>
<td></td>
<td>districts, landmarks, edges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>de Jone</td>
<td>Spatial configuration</td>
<td></td>
<td>Scale model, simulation</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Methods/Themes</td>
<td>Data Collection/Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>--------------------</td>
<td>-----------------------------------------------------</td>
<td>--------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>Appleyard et al.</td>
<td>Paths, nodes &amp; points, districts, landmarks, edges</td>
<td>Sketch maps, feature recognition (quasi-experiment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>Stea</td>
<td>Paths, points Boundaries, barriers</td>
<td>Sketch maps, interview</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>Siegel &amp; White</td>
<td>Landmarks, routes Global-survey knowledge</td>
<td>Model, simulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td>Zannaras</td>
<td>Traffic features, land use cues</td>
<td>Model, simulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Weisman</td>
<td>Spatial configuration Qualitative</td>
<td>Self-report, wayfinding (quasi-experiment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>Lindberg &amp; Gårling</td>
<td>Landmarks, routes Connections between ‘spaces’</td>
<td>Model, simulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>Evans</td>
<td>Landmark placement Spatial configuration Qualitative</td>
<td>Model, simulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>Peponis et al.</td>
<td>Building configuration Qualitative (Building scale)</td>
<td>Wayfinding Observation, Space Syntax, wayfinding (quasi-experiment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>O’Neill</td>
<td>Layout complexity ICD Building scale</td>
<td>Sketch maps, photo sorting, wayfinding (quasi-experiment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>Yeung &amp; Savage</td>
<td>Building, roads, and plazas Legibility Urban scale</td>
<td>Sketch maps, questionnaires</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>Haq</td>
<td>Spatial configuration Building scale</td>
<td>Wayfinding Observation, Space Syntax, wayfinding (quasi-experiment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>Kim</td>
<td>Paths Configuration Urban scale</td>
<td>Movement Observation, Questionnaire, sketch maps, Space Syntax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>Haq</td>
<td>Configuration Building scale</td>
<td>Wayfinding Observation, Space Syntax, sketch maps, self reports, wayfinding (quasi-experiment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>Haq &amp; Girotto</td>
<td>Configuration Building scale</td>
<td>Wayfinding Sketch maps, Space Syntax, estimation of distance, recognition test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>Yun &amp; Kim</td>
<td>Distance &amp; Turns of Paths Configuration Urban scale</td>
<td>Spatial Cognition Sketch Maps, Observation, Survey, Space Syntax</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.1.3.1 Methods for Analyzing Sketch Maps

A literature review in methodology reveals that sketch map as the main approach has always been utilized by researchers to investigate human spatial cognition/cognitive maps since the 1960s. However, sketch maps themselves are generally incomplete, distorted, and mixed with human metric or nonmetric modes of representation. Therefore, the question must be asked: how do researchers systematically encode and analyze the sketch maps?

In earlier days, researchers often use a qualitative method to analyze humans’ sketch maps. They simply calculated the frequency of physical elements appearing in humans’ sketch maps and then categorized them in the behavior mapping by percentage (Lynch, 1960; Appleyard, 1969; Francesco and Mebane, 1973; Orleans, 1973). Since the 1980s, researchers have begun to introduce statistical methods into the analysis of sketch maps. They assigned the ordinal values to the physical elements drawn by the respondent and used T-tests or correlations to compare sketch maps across different behavior settings. For example, Wiseman (1981), Peponis et al. (1990) and Haq (2001) analyzed sketch maps by counting the number of times each corridor or line was drawn; a value was given to each of the sketch maps based on a comparison of an actual plan of the setting. This was done so that the overall “correctness” or configuration of the sketches or relations between behavior mappings and objective properties of the buildings could be analyzed and compared.

Another way to analyze sketch maps is by utilizing Space Syntax. Kim (2001) and Haq (2003) drew the axial maps on the sketch maps of respondents and then calculated the syntactic properties of the sketch maps by using Space Syntax. After that, the bivariate correlations between syntactic properties of the sketch maps and real maps were calculated and compared.
2.1.4 Summary

From this literature review, it is evident that there is an extensive body of research on spatial cognition guided by different perspectives and theories. Some studies suggest that the formation of an individual's cognitive map is a result of a two-way process between an observer and his/her environment. The environment produces distinctions and relations between spaces and elements. According to his/her own purposes, the observer with great adaptability selects and organizes the environment in his/her mind and gives meaning to what he/she sees (Lynch, 1960; Ittelson, 1973).

The literature indicates that the overall environmental characteristics (street configuration and urban morphologies), and the placement of landmarks and other physical elements, such as nodes, districts, and edges, may affect cognitive mapping. It is noted that most of the early studies on measuring city structure (spatial configuration) have emphasized qualitative or inter-subjective descriptions. They have either utilized typological analysis, such as linear, parallel, and perpendicular configuration, concentric zone, sector zone and mixed concentric/sector zone (Zannaras, 1976) or inter-subjective ratings of spatial configuration (Weisman, 1981).

The few gender differences found in environmental knowledge may be explained by an individual's daily activity patterns, such as extent of setting exposure and travel mode. Individuals with the greatest extent of daily range have greater and more accurate knowledge of their environments. Research in spatial cognition must pay closer attention to individual variables, such as map experience, travel mode, and extent of home range.

A few researchers have criticized the sketch map as a tool used in visualizing the mental maps and measuring spatial cognition (Golledge, 1976; Blaut and Stea, 1974). This critique
is primarily based on the argument that there are differences in each individual's graphic abilities, which affect sketch map production. However, its extensive and continuing usage indicates that the sketch map is still an appropriate method to investigate adult's spatial cognition. In practice, researchers studying spatial cognition often combine sketch maps with other alternative methods to obtain the information, such as written description, free recall, verbal association tests, recognition test, and map labeling. However, if one wants to investigate the relationships between environmental elements, the free sketch maps together with a written description or verbalization will be enough to elicit it.

Regarding the methods to analyze the sketch maps, the literature review on this issue indicates that systematically assigning ordinal values to the physical elements that are drawn by respondents and using statistical approaches to analyze and compare them is an effective way to deal with sketch maps.

2.2 SPATIAL COGNITION, LEGIBILITY, AND WAYFINDING

2.2.1 Legibility of the Urban Environment

Lynch (1960, p. 9) defined legibility as “the ease with which its parts can be recognized and can be organized into a coherent pattern”. Following Lynch, Wiseman (1981, p. 189) defined legibility of the environment as “the extent to which it facilitates the process of way-finding”. These definitions of legibility imply that the characteristics of a physical environment can influence the development and accuracy of a cognitive map, and affect subsequent wayfinding behavior. Based on his research on wayfinding in ten university buildings, Wiseman argued that the legibility of the environment in complex buildings depends on environmental variables such as signs and numbers, architectural differentiation, perceptual access, and plan configuration (1981). Obviously the legibility is a quality of a built
environment. People can easily shape the cognitive maps of the environment and find the
destination without much effort in a more legible city or building. Downs and Stea (1973)
pointed out that people tend to draw more complete and accurate cognitive maps of a legible
environment than those of less legible ones since the more legible environment shows more
coherent and orderly pattern. These coherent and orderly patterns form a hierarchical
relations between urban elements, which fit the way in which our minds work.

Legibility is an important aspect of urban design, and it is obviously related to spatial
cognition and in particular to wayfinding performance. The history of cities tells us that
humans are always searching for a hierarchical space organization and the street pattern as
fundamental in forming a coherent mental image of the environment: a closed order (the
walled city) in the Middle Ages; a structured order in the Renaissance; a functional order in
the Industrial era; and an open order in our modern era (Curran, 1983). So what is the
criterion of legibility? And what is a legible urban environment? It seems that there is no
definite answers to those questions. Maybe some theoretical arguments will shed light on it.

Churchill (1962) stated that legibility develops from a grand scheme like the grid. Legibility
requires attention to topography, variety in types and sizes of streets, promoting a certain
degree of homogeneity within a small area but varying or differentiating in styles from area to
area. Lynch (1960) argued that a legible city would be one that has districts, landmarks, or
pathways that are easily identifiable and are easily grouped into an over-all pattern. Devlin
(2001) indicated that when we describe a building, neighborhood, or city as legible, we just
say that we can ‘read’ it or understanding its relationships and that they make sense and
create a pattern that enable us to find out a way (p. 192).

In practice, it is difficult to directly measure the legibility of an environment. Generally,
depending on definitions of legibility and research purposes, scholars have used two indirect
methods to measure the degree of legibility of an environment. One method is to measure wayfinding performance, which is the outcome of legibility of an environment on spatial cognition. Some studies, for example, measure the time that people need to find the destination from starting points or interview people about their wayfinding process in an experimental setting (Haq, 2001, Wiseman, 1981). For investigating the effects of spatial configuration on wayfinding performance, Haq (2001) used time to measure human subjects' wayfinding performance to reflect the legibility of the environments of three hospitals during their exploratory and directed search. In another study, Wiseman (1981) used self-reports to investigate the relationships between a legibility difference in the environment (the degree of layout complexity) and people’s wayfinding performance.

The second method is to measure the accuracy of sketch maps of a built environment or the correctness of recognizing pictures of the environment in a simulation experiment or natural setting (Evans, 1980, Evans et al., 1984; Yeung and Savage, 1996). For example, Evans et al. (1984) investigated the relationships between two landmark conditions in two different grid patterns (nongrid and grid) and spatial cognition in a simulation environment. They asked respondents to view a film and then let respondents put photos taken from the film in sequential order and indicate their degree of confidence in recognizing the scenes. Yeung and Savage (1996) let respondents identify the roads, buildings, and plazas in a road map of an urban center in Singapore without road names on it to investigate the relationships between legibility and personal experiences. For more valid measurements, researchers combine these two methods together to achieve more robust results.

2.2.2 Wayfinding

The previous literature review on legibility reveals that the legibility of an environment is vital to the human spatial problem solving problem, especially the wayfinding act. Although the
field of wayfinding is not the focus of this study, reviewing some literature on wayfinding will shed light on my theoretical arguments and methods. Thus, the definitions of wayfinding and process will be discussed in this section.

Golledge (1999, p. 6) stated that “wayfinding is the process of determining and following a path or route between an origin and destination. It is a purposive, directed, and motivated activity. It may be observed as a trace of sensorimotor actions through an environment.” He also argued that the legibility of the environment influences the rate at which an environment can be learned.

According to Carpman and Grant (1993, p. 66), “wayfinding refers to what people see, what they think about, and what they do to find their way from one place to another…Wayfinding involves five deceptively simple factors: knowing where you are, knowing your destination, knowing and following the best route to your destination, recognizing your destination upon arrival, and finding your way back.” Similarly, Passini (1984) pointed out that wayfinding is a process that includes information processing, decision making or planning, and decision execution.

No matter how it is defined, the term ‘wayfinding’ is commonly used to refer to the act of finding the path or paths leading to one’s destination and finding that destination itself. It is an individual’s ability to navigate and find a particular point within an environment.

According to Golledge (1999), wayfinding is different than navigation based on the guiding process and the scale of area or space. Navigation is used to guide humans traveling over undistinguished territory either water or air. Navigation usually takes place over very large natural settings and may involve the use of distant elements as a source of direction, such as the stars. The sea and desert are some settings where navigation is required. By contrast,
Wayfinding is performed in comparatively small areas. However, they are usually too large to be understood at once so humans need to build cognitive maps to move in them. Cities and complex buildings, such as hospitals, transportation centers, and airports are some example settings for wayfinding.

Wayfinding includes two components: the actual physical environment and people. These two components produce the act of wayfinding. Therefore, exploring the interactive process between a human’s wayfinding act and environmental variables becomes an important aspect for wayfinding research. Much research has been conducted to investigate and understand the wayfinding process and techniques to facilitate wayfinding performance, spatial cognition and orientation, travel planning, route selection, and so on (Gårling et al., 1995).

For example, in 1981 Weisman used 73 self-reports regarding wayfinding in ten university buildings and found that the ‘simplicity’ of the floor plan configuration as rated by 100 judges was a strong predictor of self-reported wayfinding performance. Later in 1989, he considered wayfinding from both perceptual and cognitive points of view and proposed that four kinds of environmental information are important: signs and numbers, architectural differentiation, perceptual access, and plan configuration.

Wayfinding process can be broadly categorized into two models (Haq, 2001). Many researchers (Wiseman, 1981, Passini, 1984) argued that there is some kind of internal process (cognitive mapping) between the environment and wayfinding behavior. First the environment affects human spatial cognition and then the process of spatial cognition influences the subsequent wayfinding act. In contrast, a few researchers accept the theories of ecological perception proposed by Gibson (1979) and hypothesize that the environment directly acts upon wayfinding behavior without a cognitive process (Heft, 1983).
While there exists a huge difference between the two models, both of them reveal an important assertion that wayfinding and environmental learning take place through movement within it.

2.2.3 Summary

The literature review in this section indicates that the degree of legibility of a building or urban area inherently influences people’s wayfinding performance. People could easily shape their cognitive maps in a more legible environment; a clear image of the environment will contribute to their wayfinding performance in the future. While the legibility of the environment depends on many characteristics, the spatial configuration of a building or urban area, such as layout complexity, relations between spaces, and patterns of streets (Lynch, 1960; Churchill, 1862) is the primary characteristic. In addition, the research in wayfinding studies reveals another important argument that human spatial cognition takes place through movement within environments. Overall, movement is recognized as the precondition of spatial cognition and wayfinding performance.
### 2.3 SPACE SYNTAX

As discussed in the literature review section (Section 2.1.3), the Space Syntax approach has been utilized in cognitive studies since the 1990s. Some problems in environmental cognitions and wayfinding studies, which have not been fully investigated due to a lack of an appropriate technique, are being explained and solved by using the Space Syntax methodology. These issues have been addressed by many researchers in their theoretical arguments.

Kim and Penn (2004) argued that previous studies of spatial cognition are not clear on the precise nature of the cognitive representation itself. Two primary forms of representation are posited. The first comprises an explicit representation of route; the second proposes that a more or less realistic map must be constructed because it is only this that can account for our ability to infer new routes and to relocate ourselves by reference to cues once lost. Also, they stated that there is a gap in understanding the relationship between configuration and cognitive representation. There seem to be two causes for this gap. First, there has not been an analytical method for objectively describing configurational characteristics of urban environments. On the other hand, those studies that have objectively investigated configuration on the local characteristics have mostly focused on the immediate characteristics of spatial configuration and not on their overall relational context (Penn, 2003). Methods for analyzing global characteristics have been qualitative (Zannaras, 1976) and inter-subjective judgment (Weisman, 1981), rather than analytical. This is perhaps not surprising because methods for analysis of relational properties of configurations --- those relating parts to the whole pattern --- are not widespread. In fact, use of the world *global* to describe those aspects of spatial configuration relating a part to the whole is not fully investigated in the cognitive field. Second, mainly because of the different research viewpoints in studying relationships between syntactic approaches to spatial configuration
and cognition approaches to spatial configuration (e.g., O’Neill, 1991a) the interaction between syntactic characteristics of spatial configuration and cognitive maps in spatial cognition has not been extensively investigated (Kim and Penn, 2004).

In this regard, the next two sections will discuss what Space Syntax is, its grounded theories, the methodology relevant to measuring topological relations of spatial configuration, and empirical studies that have utilized it.

### 2.3.1 Space Syntax Theory and Methodology

Space Syntax is primarily a method to measure the topological relationships between one space to all other spaces.

The theoretical ideas for Space Syntax were first presented by Hillier and Hanson (1984) in their book *The Social Logic of Space*. They suggest that in both cities and buildings, the relationship between form and function passes through spaces. Form and function in space are not independent. Hillier stated (1996), “At the most elementary level, people move in lines, and tend to approximate lines in more complex routes. Then if an individual stops to talk to a group of people, the group will collectively define a space in which all the people the first people can see can see each other” (p. 153). The fundamental correlate of the spatial configuration is *movement*. This is the case both in terms of the determination of spatial form, in that movement largely dictates the configuration of space in the city, and in terms of the effects of spatial form, in that movement is largely determined by spatial configuration. Based on empirical studies, Hillier (1996) argues that “the structure of the urban grid considered purely as a spatial configuration, is itself the most powerful single determinant of urban movement, both pedestrian and vehicular. Because this relocation is fundamental and lawful, it has already been a powerful force in shaping our historically evolved cities by its
effect on land-use patterns, building densities, the mixing of uses in urban area and the part-whole structure of city” (p. 152). The overall distribution of movement in the area is largely determined by spatial configuration --- the theory of “natural movement” (Hillier et al., 1993).

Above all, it can be inferred that spatial configuration is not only the driving force for human activity within urban environments, but also it is this that first influences human cognition and further determines human activity within urban environments (Jiang, 1998) since spatial cognition is shaped by movement within spaces. Therefore, if the building or urban area is considered as a system that carries movement from every space to every other space within the system, certain spaces (those that are most directly connected to every other space in the system) will tend to attract higher densities of movement, which also will greatly influence cognitive maps. As a result, individuals will tend to view the buildings or physical elements in this urban area as references for wayfindings. Later, the buildings or other physical elements that comprised the urban environments in the area will be reflected clearly in the individuals' cognitive maps.

Previous literature in spatial cognition also revealed that an individual's first and primary spatial cognition is based on topological information, not metric information (O'Neill, 1991b). Actually, Space Syntax describes the topological relationships of spatial configuration rather than metric distances and allows rigorous analysis of building and city structures that is both theoretical and mathematical. Since the fundamental assumptions underlying Space Syntax are based on human cognition and behavior, it would appear that Syntax could be strongly linked with Environment and Behavior (E & B) and spatial cognition research. As Haq (2001) argued, “Space Syntax does seem to be a useful theory and methodology for understanding the role of environmental form from the point of view of topological relations in the study of environmental cognition and human wayfinding behavior” (p. 64).
Regarding urban areas, Space Syntax is based on the fact that the urban environment is an interconnected space where spaces link to other spaces. The Space Syntax approach provides an urban morphological representation by looking at only public spaces (open spaces) (Figure 2). These public spaces look like a beaded ring system in which space widens to form irregular beads, and narrows to form strings. At the same time the beads join so that there are always choices of routes from any one space to any other space (Hillier and Hanson, 1984, p. 90). Based on the analogy of the beaded ring system, there are two ways to represent urban environments by only concentrating on public spaces: *convex polygons* and *axial lines*.

![Figure 2: The Relationships Between Public Open Spaces (black) and Buildings (White) in an Urban Environment.](image)

A convex polygon is a polygon in which no line drawn between any pair of points within that polygon goes outside of the polygon. They are those spaces within which all points are directly visible from all other points within the space (Figure 3)
Axial lines deal with linear extension and are represented by an axial map (Figure 4). The axial map is comprised of the fewest and the longest lines that cover all the available connections from one convex space to another. Axial lines represent the longest views across spaces that capture the sense of what a person sees while moving in urban areas. On the other hand, it also represents a person’s movement behavior since people always walk in a straight line to minimize the distance, not a curved line. In this regard, the axial lines simplify the complex urban environment and connect human spatial cognition and movement behavior together.
Figure 4: Axial Map of an Urban Area.

In the Space Syntax approach, an axial map is transformed to graphs by replacing each axial line, which represents an open space, with a node, and by replacing the intersections between lines with lines. Thus, the graph of each line will be drawn in terms of its relations with the other lines, which is also called a justified permeability graph. Then, based on the graphs, how each space is related to the other spaces can be described and calculated. The primary value that describes how one space is related to all the other spaces (topological relations) is total depth (TD). TD represents the number of turns (steps) that one needs to take to move from one space/line to another space/line. As a result, the topological graphs are transformed into numeric values, which objectively measure the spatial configuration (Figure 5). For each space/line, total depth could be calculated by averaging the depth in relation to each space/line in the urban space, which represents a global property. Besides the total depth, just several depths or steps could be calculated for each line, for example, 3 or 4 depths or steps. These relations between spaces are called a local property. More often
than not, researchers use 3 depths to represent the local properties between spaces since it generally covers a neighborhood scale.

The depth is the basic and most important value for describing topological relations between spaces. Based on it, algorithms for calculating the other important syntactic properties such as global integration and local integration are being developed. In the next section, these syntactic values will be described in detail.
Figure 5: Transformation from Axial Map to Justified Permeability Graphs.
2.3.1.1 Syntactical Properties

For urban environments, an axial map gives the opportunity to objectively measure spatial configuration of the urban environment. There are three important syntactic measures of spatial configuration of an axial map: connectivity, integration (global and local), and intelligibility. Regarding convex space, another syntactic property --- visibility of a convex space --- is more appropriately used to study an urban environment (Hillier and Hanson, 1984, Hillier, 1996).

Connectivity  Connectivity is the measure of how well an axial line is intersected by other lines. In principle, there is no non-intersected lines in any urban environment (i.e., each space is accessible from every other space in the city). For example, the connectivity for axial line 1 in Figure 5 is four, since there are four axial lines (2, 3, 4, 5) directly intersecting it. In the mean time, it is indicated that the length of an axial line has some correlation to connectivity indexes, that is, there are more possibilities for lengthy lines to be intersected by others (Jiang, 1998). A modification of connectivity is a control value, which measures how each axial line controls access to immediate neighbors (i.e., those lines intersected by the current one). Both connectivity and control value are local measures since they only take into account relationships between a space and its immediate neighbors (Jiang, 1998).

Integration  Space Syntax quantifies the way in which an axial line is connected to another or to all the other lines. A connection between two axial lines is said to be shallow or deep when a few or many intervening lines have to be traversed when going from one to the other. A space is said to be integrated, when all other spaces of the urban environment are relatively shallow from it. In other words, it is a function of the mean depth (i.e., the mean number of axial lines and connections that one needs to be traversed when moving from one space to all other spaces in the system). In this regard, integration is a measure of
syntactical accessibility. The steps for calculating integration values can be found in Section 3.3.1. Thus, from a space with a high integration value, fewer changes in direction are necessary to move from that space to all other spaces in the system (Peponis and Wineman, 2002; Penn, 2003). As Figure 5 shows, axial line 1 is shallower than axial line 8, since it has a relatively lower value of mean depth than that of the axial line 8.

In this way, integration of a line is by definition a value that indicates the degree to which a line is more integrated, or segregated, from a system as a whole. The higher the integration value of a line, the less its depth, which means the line has high syntactic accessibility in the system. Integration is a global measure (Rn), as the calculation of integration is based on the total depth. However, if a number of depth, instead of all depth, is considered, then the integration is called local integration, which measures the accessibility three or more steps away based on research purpose (Peponis and Wineman, 2002; Jiang, 1998).

If an axial map is displayed by using graduated color symbology based on the integration values, the spatial configuration of the whole system will be visualized and easily compared between different urban environments. Generally, an accepted rule to represent integration is using warm colors, such as red or orange, to represent high global or local integration (high integration values) and cold colors, such as blue or green, to display high global or local segregation (low integration values) (Figure 6). The integrated core represents the 10% highest integration values (Hillier, 1986, 1996).

**Intelligibility** Hillier (1988, 1996) defined intelligibility as “the degree to which what can be seen and experienced locally in the system allows the large-scale system to be learnt without conscious effort” (Hillier, 1996, p. 215). He argued that a strong association between local information and global information makes people easily form the overall spatial configuration in their minds. Intuitively, this means that in a layout of high intelligibility,
information about local connectivity allows a person moving through the system to understand the overall structure of the configuration. In practice, the intelligibility value is calculated by the degree of linear correlation between connectivity and the global integration value (Hillier and Hanson, 1984). The stronger a correlation, the more global configuration of a space may be inferred from its directly observable local connections. Intelligibility values can be used to quickly compare spatial configuration of different urban environments. In addition, Hillier et al. (1992) observed that intelligibility appears higher in a well defined “named neighborhood” perceived by residents in London.

If the intelligibility concept is compared with Lynch’s Legibility concept (1960) --- the ease with which its parts (landmarks, paths, districts, edges and nodes) can be recognized and can be organized into a coherent pattern --- it is evident that both address clear or coherent configurational properties. These clear and coherent configurational properties can be learnt without efforts or easily formed in a cognitive map. In this regard, we can understand that when people move around in an intelligible environment, they are able to acquire the global relations of spaces based on local information without much effort. This global information can be easily organized into a coherent and clear image in people’s minds.

The legibility of the urban environment depends on many aspects such as spatial configuration, characteristics of physical elements, signage, and so on. The previous literature indicated that the characteristics of spatial configuration of an urban environment is one of important aspects that may affect an individual’s perceived legibility of the urban environment. This study utilizes “intelligibility” as an objective measure to describe the overall spatial configuration of the urban environment.
Visibility (iso) Visibility is a property derived from a convex space. It is the total set of all points that can be seen from a selected point in a spatial configuration. For any “vantage point” $x$ in a spatial configuration $D$, $V_x$ is the set of points $V$, and all $V$ are visible from $x$. Therefore, this is called the visible set or isovist at “vantage point” $x$ (Figure 7):

$$V_x = \{ V \in D: V \text{ is visible from } x \}$$

Based on these three components of the boundary of an isovist, the measure of visibility is then defined as the area of the isovist, $A_x = A(V_x)$, which measures how much space can be seen from $x$ in terms of the area (Benedikt, 1979, p 49).
Figure 7: The Visibility of Selected Point “x” in a Spatial Configuration. Illuminated Areas Represent $V_x$, which is the Isovist for Location of x (Based on Benedict, 1979, p. 50).

The isovist of an individual space is calculated by putting a high resolution grid on its plan and then calculating the isovists of each square of the grid. Next, all the squares of the grid in that individual space are chosen and “one step” away from the chosen squares of the grid is calculated. All the squares of the grid that are one step away will be the isovist of that individual space (Benedikt, 1979; Turner, 2004). The resolution of the grid is selected by the researcher. Higher resolutions grids produce more accurate isovist values.

Visibility analysis is appropriate to measure the convex space, especially those spaces with a definite boundary, such as the interior spaces in the buildings. Many studies have utilized it to objectively measure the layout of the building (Haq, 2001; Toker, 2003). In an urban environment, the visibility is utilized to analyze open spaces, such as plazas and squares.
2.3.2 Space Syntax, Movement, and Urban Environment

In the past decade, extensive empirical studies have demonstrated that there is a strong correlation between spatial configuration (particularly integration) and movements.

Hillier (1985) combined observation and Space Syntax to investigate the relationships between pedestrian movement and spatial configuration in Barnsbury, a residential neighborhood in London. The pedestrian movement was observed and measured by a number of people per 100 meters in the streets of the neighborhoods at different times. Results showed that there was a strong positive correlation between integration and the density of pedestrians moving along street lines. Hiller inferred that the correlation results from the properties of the urban layout. The most integrated spaces in Barnsbury, its “integration core”, traverse its center and link to the periphery, thus facilitating movement through the area.

Later, Hillier et al. (1987) also found that there was a strong positive correlation between integration and the square root of moving pedestrians in four London urban areas. In contrast, less consistent correlations were reported for three suburban areas. The three suburban areas were more substantially segregated than the other urban areas and there was a poor relation between local and global integration, which means a very unclear relation between the local and global structure. More importantly, when comparing four London urban areas, the correlations between integration and movement were better in areas that had stronger correlation between integration and connectivity (i.e., areas with higher intelligibility). Based on this, it is assumed that when an area is more intelligible (the stronger correlation between local and global structure), it is easier for people to understand
the urban system clearly and know where they are.

Following Hillier, another study used Space Syntax and observations to investigate the relationships between spatial configuration and the density of movement in six Greek cities (Peponis et al., 1989). The results indicated that the integration was the most frequent and most reliable predictor of the density of movement in any particular space than the other syntactic values, such as connectivity, choice values, and length.

Peponis et al. (1997) investigated if the distribution of integration values by axial line is correlated with the distribution of vehicular traffic densities in Buckhead at Atlanta. After analyzing the data from the actual observation, six-year traffic volume data recorded by DOT and Integration values measured by Space Syntax, it was found that the correlations were quite good (between 0.68 and 0.78, P< 1%). For achieving a more reliable and robust result, they again recorded both vehicular and pedestrian densities at 70 ‘gates’ in Buckhead and 36 ‘gates’ in downtown Atlanta. Gate counts measured the number of vehicles, or the number of people that cross street section during a given time interval. Similar to the previous investigation, there were clear positive correlations between the number of cars and integration value of the corresponding spaces for both Buckhead and downtown Atlanta. In the meantime, correlations between densities of pedestrian movement and integration were strong in both areas. Their research suggested that an underlying lawfulness regarding the correlation between spatial configuration and patterns of movement can be clearly identified in a city like Atlanta experiencing fast growth and far reaching transformations.

Dawson (2003) used Space Syntax to examine the effect that spatial configuration of Canadian arctic communities has had on patterns of movement and social interaction among Inuit inhabitants. Based on an over two-month field observation in the hamlet of Arviat, Nunavut Territory, the analysis revealed that integration was a much better predicador
of vehicle traffic than pedestrian traffic. This result strongly contradicted the findings of a number of studies conducted in European and North American cities, where much stronger correlations have been detected between integration and pedestrian movement. The researcher suggested that this contradictory result is probably related to both the functional factors that “deform” the grid layouts of Arctic communities and to the unique lifeways and cultural values that continue to characterize Inuit society.

2.3.3 Space Syntax and Spatial Cognition

In addressing the importance of intelligibility, Hillier (1988) argued that there is a fundamental difference between old and new residential environments. The old urban space, he believes, is intelligible when compared to the new modern urban space, which emphasizes over-localized concepts like “enclosure”. The new and “enclosure” type plans developed by designers based on the concept of the small, relatively bounded community, that form an identifiable unit of a larger whole, are intelligible as plans from the air. But if we try to move around them, we lose all sense of where we are. The similarity of the parts, and their predominantly localized reference points, guarantee that on the ground they lack intelligibility. In contrast, the old towns, such as the French town of Apt, Vaucluse, have the opposite properties. From the air, the plan of this old town appears disordered since it lacks the kind of regularity that we identify as urban order. But on the ground, it has a degree of natural legibility, which means that we do not need signs to tell us where to go. We know how to read the town, and how to use it.

Hillier (1988) suggested that the answer to this puzzle lies in the following: first, the old town has the general topology of a grid, being made up of a series of islands of outward-facing buildings, each surrounded by a ring of open space, which forms part of an interconnected net. Based on the differences of length and width of the spaces, one can see changes as
he/she moves about. Second, this gives clues where one is and how to move for the next step (Hillier et al., 1988). Hillier refers to such urban structures as intelligible ones. In this regard, he indicates that the “urban system is more understandable if one can acquire the global relations of configuration based on local information or structure” (p. 78). In practical terms, the intelligibility is measured by the degree of fit between global integration and connectivity in an area. According to Penn (2003), as areas become less intelligible, they also appear to lose the relationship between spatial integration and movement. Thus, intelligibility becomes an important concept in the field of urban design.

One of the first studies that used the Space Syntax approach in studying spatial cognition was conducted by Peponis, Zirming, and Choi (1990). They investigated cognition and wayfinding performance in a complex hospital by using Space Syntax techniques. In this study, they proposed the concept of a “search structure” that links the inherent intelligibility of a building to wayfinding performance. They also considered both open exploration and directed searches as two kinds of wayfinding. The results indicated that spatial cognition depended in part on local information, in part on memory of those areas of a building already explored, and in part on the ability to project or develop hypotheses about those parts of a building that had not been explored so that exploration could maximize new information. From this finding, it is inferred that intelligibility may facilitate wayfinding performance since people need to shape a cognitive map about those parts of building that haven’t been explored so that they can maximize the fruits of wayfinding act.

Later Haq (1999) used a similar methodology in a larger and more complicated urban hospital. With data collected from 32 young subjects he found Integration as an important predicator of wayfinding. Additionally he claimed that since wayfinding is a conscious act of choosing one’s paths, and since Space Syntax values are strongly correlated with wayfinding use of these paths, then perhaps Space Syntax could also be a useful tool to
study spatial cognition. Haq also showed that with increasing familiarity, correlations of space use and global variables increased while correlations with local variables decreased. In other words, as people learn more and more about their settings, their reliance shifts from local to global environmental variables. This result also had been supported by his later study (2001).

Chang and Penn (1998) investigated pedestrian movement behavior in two multi-level urban complexes, the Barbican and the South Bank Center in London. Their findings are directly related to the issue of cognition because both areas are said to be maze-like and confusing. Space Syntax analysis found both are also relatively unpredictable --- as there was a low overall correlation between axial integration and observed movement. Chang’s concern was to develop a method of disaggregating the various variables that might contribute to the way that people move through these complexes so that they could be combined into a single predicative model. He was then able, by removing one variable at a time, to evaluate its effect on observed movement. In this way, he suggested the relative importance of vertical level changes, changes of direction, visibility of stairs, major attractors and generators of movement, and a range of other factors in determining movement patterns.

Kim (2001) conducted a study of the Hampstead Garden Suburb area of North London to understand the relationship between configuration, cognition, and behavior. He combined observations of spatial behavior; questionnaire interviews, including a sketch-mapping with a sample of 76 local residents; and used Space Syntax to analyze the spatial configuration of the area embedded in its surroundings and the sketch maps. The suburb is divided into two halves; the old half is relatively intelligible and the new half is significantly less. By examining the response of those living in each half separately, he was able to draw some significant conclusions on the effects of spatial configuration on the way that residents understood their neighborhood and the role played by the intelligibility in that. After
investigation, Kim found that spatial configuration was correlated with observed movement, with the more intelligible area showing stronger correlations. This area was also found to be more “legible” by the residents who perceived their neighborhood to be of a greater size. Second, he applied Space Syntax to analyze sketch maps. He simply counted the frequency with which features occurred in all sketch maps among the same population and found strong correlations between axial integration in residents’ sketch maps, frequency of physical elements (streets and roads), and axial integration of the real map. Also, correlations were found between sketch map integration and observed movement. Again, correlations were more powerful in the more intelligible area than the less intelligible one.

Hag and Girotto (2003) investigated the relationships between intelligibility, spatial cognition, and wayfinding performance in two complex hospitals, City and University Hospital. The intelligibility of City Hospital ($r=0.557$) is lower than that of the University Hospital ($r=0.837$). Ninety six participants who had never been there before explored the setting, completed wayfinding tasks, pointed to an unseen destination, estimated distances between them, and drew the sketch maps from memory. The two hospitals were measured in terms of intelligibility, integration, and connectivity. The sketch maps were measured in terms of number of lines, number of nodes, number of locations, composite grade, sketch map intelligibility, and topological accuracy. Analysis indicated that mean integration values of lines in sketch maps were strongly correlated with the real integration values in two hospitals ($r=0.931$ and $0.876$). More important, the mean topological accuracy for the University Hospital (mean=6.18) was found to be greater than that for the City hospital (mean=3.27). In addition, the mean intelligibility of the sketch maps drawn for University Hospital (mean=0.83) was greater than the mean intelligibility of the sketch maps of the City Hospital (mean=0.64).

Lay et al. (2005) investigated the relationships between spatial configuration, spatial behavior and spatial cognition in the central area of Porto Alegre and the effects of the
recently constructed Market Metro Station on the legibility and imageability of the area. They used a Space Syntax approach to objectively measure spatial configuration, sketch maps to measure spatial cognition, questionnaires, and observation (behavior maps) to document people’s spatial behavior. Results showed that the imageability of Market Station is considerably low when compared to the most mentioned landmarks in the area. Findings suggested that the reduced visibility of the building and lack of aesthetic attributes adversely affected the imageability of the newly constructed Market Station. Based on the findings, the researchers concluded that the syntactic description of spatial configuration can be combined with the theoretical positions of spatial cognition to investigate human spatial experience. “The incorporation of spatial configuration implies a specific inception in understanding the role of spatial configuration in environmental cognition and behavior” (p. 135).

2.3.4 Summary

The literature review on Space Syntax indicates that Space Syntax is an analytical tool that can be utilized to quantify the various levels of topological relations within an urban environment. This makes it an important tool in cognitive studies since the evidence from spatial cognition studies has pointed to the importance of topological relationships in comprehension of a built environment.

Most studies that utilized Space Syntax methodology focused on the building environment. Little research has been applied to the urban environment. On the other hand, the previous literature review section on wayfinding models (Section 2.2.2.1) indicated that many researchers believe there exists a cognitive process mediating between spatial configuration and spatial behavior. Therefore, much of work has been done to investigate the relationship between spatial configuration and spatial behavior, particularly the wayfinding act at the
building scale. However, few studies investigated the relationship between spatial configuration and spatial cognition in an urban environment using Space Syntax. In other words, there is limited evidence about how representations of cognitive maps link to the various properties of spatial configuration. Therefore, this study attempts to fill this gap and contribute to the knowledge of environmental cognition.

2.4 CONCLUSION ON LITERATURE REVIEW

From a literature review on existing studies of spatial configuration, spatial cognition, wayfinding, related variables, and the measurements, one can group these concepts into general categories as “physical environment”, “spatial cognition”, “personal experiences”, and “spatial behavior”. The literature review reveals three important points:

1. **Physical environment** affects people’s **spatial cognition**. It is the root of our understanding of the whole urban environment. Further it affects people’s wayfinding performance and spatial-decision, such as choosing roads to reach a destination. Moreover, **personal experiences**, such as socio-economic characteristics, commutativity, associativity, location of home, length of residence, travel mode, and other variables affect people’s spatial cognition.

2. Stea (1969) stated that **cognitive maps** reflect information about the hierarchical arrangement of points in space, with respect to relative distance and size. In this regard, this is also linked to Space Syntax theory in which “relative distance” could be interpreted not as a metric distance, but as a number of steps or depth when individuals include particular physical elements of the urban environment in their cognitive maps. On the other hand, cognitive maps also contain information about the degree of interconnectedness among points in the geographic environment. At this point, both prepositional (cognitive representations and their relations) and analogical (one to one relationship between cognitive representation and reality) models have some connection with the theories of
Space Syntax.

3. Space syntax can be innovatively utilized as a tool to quantify various properties of the spatial configuration, regardless of city scale. Since the 1990s, many researchers have utilized it in cognitive studies.

Based on the literature review, it is possible to represent the relationships between the physical environment, personal experiences, spatial cognition, and spatial behavior in a general conceptual framework (Figure 8). This conceptual framework points to the effects of an urban environment and personal experiences on spatial cognition and further spatial cognition on spatial behavior, such as wayfinding performance.

In addition, a literature map was developed to provide the conceptual framework of this study (Figure 9). The literature map reveals that limited studies have been conducted to investigate cognitive representations and the urban environment using Space Syntax, particularly at an urban scale.
Figure 8: General Conceptual Framework Representing the Relationships Between Physical Environment, Spatial cognition, Personal Experiences, and Spatial Behavior.
Relational Elements/ Spatial Config.

- Zannaras, 1976, City Structure and Cognitive Maps
- Jonge, 1962, Spatial Configuration and Cognitive Maps
- Tzamir, 1975, Path Distance, Angle and Cognitive Maps

PHYSICAL ENVIRONMENT


Discrete Elements

Hiller, 1985, 1987; Peponis et al., 1997, 1989; Dawson, 2003 Integration and Movement

SPATIAL COGNITION

- Hiller, 1988, Intelligibility, Legibility and Wayfinding (theoretical arguments)
- Kim, 2001, Intelligibility, Cognition and Behavior

City and Neighborhood Scale (using Space Syntax)

- Weisman, 1981, Floor Configuration and Wayfinding
- O’ Neill, 1991, InterConnective Density and Wayfinding

Architectural and Building Scale (using Space Syntax, except Wiseman and O’Neill)


PERSONAL EXPERIENCE

- Horton & Reynolds, 1971, Commutativity, Associativity, Location and Cognitive Maps

SPATIAL BEHAVIOR
CHAPTER 3: CONCEPTUAL FRAMEWORK OF THE STUDY

The main purpose of this study is to investigate the relationships between inhabitants’ spatial cognition and overall spatial configuration of the environment. By studying this, we are able to understand how people construct the urban environment in their cognitive maps and the role of spatial configuration in this process. The conceptual framework is based on the following four arguments: first, the urban environment consists of physical elements (discrete elements) and topological relationships of these elements, which are understood by humans as cognitive representations in their minds; second, city structure or spatial configuration inherently affects humans’ spatial cognition; third, personal experiences affect an individual’s spatial cognition; and fourth, Space Syntax theory and its methods provide appropriate tools to describe and analytically measure topological relationships of the urban environments.

3.1 THE CONCEPTUAL MODEL IN THIS STUDY

The literature review indicates that spatial configuration plays an important role in people’s spatial cognition. The spatial configuration can be measured by Space Syntax. Four syntactic properties quantify objective structures of spatial configuration: integration, connectivity, visibility, and intelligibility. Evidence has shown that streets with high values of integration (i.e., high syntactical accessibility) attract a higher density of movement in urban areas. On the other hand, the literature on spatial cognition indicates that humans’ cognitive maps are developed through movement. Movement around the city gives the human a sense of global and local relationships of physical elements comprising the urban environment. Inherently, some areas in the city will attract more movement because of their higher syntactical accessibility (i.e., least mean depths with the other streets). If individuals tend to use certain paths (i.e., shallower or easily accessible) more often than others, it is
possible to assume that certain physical elements, such as landmarks and nodes that are on these paths, will be reflected clearly in their cognitive maps. Thus, this will contribute to the legibility of the environment and the wayfinding performance of individuals.

Connectivity is a local syntactic measurement, which takes into account relationships between a space and its immediate neighbor spaces. Streets with high connectivity values will be more accessible from different directions and give people more possible choices. These streets, in turn, are expected to have high use by people. In this regard, it is possible that physical elements in these spaces will leave a strong image in people’s cognitive maps.

Visibility is important and could be linked to both axial maps and visibility graphs. An axial map is comprised of axial lines. Axial lines are the longest lines of view that cover the space. Intuitively, two individuals standing at each end of an axial line will be able to see each other. Integration values are calculated based on an axial map. A higher integration axial line means individuals could see all of the other spaces with less turns or steps. Visibility graphs also become important since they could elicit areas that are visible from certain points (Benedict, 1979). High visibility of some open spaces in urban areas, such as squares and plazas in cities, indicates that people can easily view them from different perspectives when moving around the city. Further, it will leave an impressive image in their cognitive maps.

On the other hand, as we know from literature, humans’ memories appears to have a hierarchical structure associated with spatial images (Anderson, 1995; Stevens and Coupe, 1978) since individuals need to transcribe short-term memory to long-term memory (i.e., cognitive maps of urban environments). Thus, if the rules for building a hierarchical structure of area in subjects’ cognitive maps fit the objective characteristics of the spatial configuration (measured by Space Syntax as “intelligibility”), the area will be more legibly perceived by people. As a result, the degree of importance of cognitive representations and their
topological relationships will be clearly reflected or recalled in subjects' cognitive maps according to this hierarchical structure of memory (Long, Baran and Moore, 2007).

Spatial cognition is mainly studied through representations of cognitive maps and the concept of legibility. In this study, from the five elements that commonly appear in cognitive maps, landmarks, paths, and districts are particularly important but edges and nodes are not considered. There are two reasons for this. First, based on previous studies on legibility (Table 1), an edge is a less important element compared to the other four elements. On the other hand, based on the definition of ‘edge’ (Lynch, 1960), edges are rivers, railroads, walls, and other linear elements, which are used as barriers. As a result, residents have difficulty moving in it. Later, it is less recalled by the residents in their cognitive maps for orientation. Second, a node is an important cognitive representation and can be related to the concept of "visibility". Human wayfinding behavior is closely linked to the visual/perceptual access of the space. People tend to go where they can see (Wiseman, 1989). If all else is equal, humans tend to continue along the same line and divert from the line of movement when a new view allows individuals to see more space and activity or provides a longer view and lets them see further ahead (Peponis et al., 1990). In this regard, high visibility of open spaces, which takes into account the visibility as considered in "visibility graphs" and visibility as considered in "axial maps", will leave a clear image in human minds (Long and Baran, 2006). Although nodes are important, based on the characteristics of the study areas and the result of the first pilot study conducted in July 2006, there were a very limited number of nodes perceived by residents in the study areas, which limited the exploration of nodes in this study.

Unlike landmark, node, and path in cognitive maps, the district in cognitive maps is a middle-scale area within the city. It can be a neighborhood or community reflected in mental maps. So, in this study, the test will attempt to find if a more intelligible a neighborhood or
community (measured by the value of intelligibility) is a more legible environment. To my knowledge, only one study has explored this and found a positive relationship between intelligibility and legibility in the urban environment (Kim, 2001). In addition, the investigation of the relationships between intelligibility and the perceived boundary of neighborhood is rare in the literature review, however, its exploration is out of the scope of this study.

The literature review has shown that personal experiences also affect people’s spatial cognitions (Appleyard, 1969; Orleans, 1973; Hart and Moore, 1973). This includes five key indicators: familiarity, travel mode, location of home, associativity, and socio-economic characteristic. Since exploration of personal experiences is not the focus of this study, only familiarity as a moderating variable will be considered.

Based on the above review, a conceptual model was developed and used to study the relationship between spatial configuration of the urban environment and human’s spatial cognition (Figure 10).
Figure 10: Conceptual Model in this Study.

Reflected in Cognitive Maps as Spatial Configuration Measured by Space Syntax

- Global Integration
- Local Integration
- Connectivity
- Intelligibility

PERSONAL EXPERIENCES
- Familiarity

PHYSICAL ENVIRONMENT

Objective Evaluation
- Discrete Elements

Subjective Evaluation
- Reflect in Cognitive Maps as
  - Landmarks Paths
  - Legibility

Relational Properties
- Subjective Evaluation
3.2 RESEARCH QUESTIONS

In general, this study is focused on exploring the relationships between residents’ spatial cognition and overall spatial configuration of the environment. In light of the conceptual model guiding this study (Figure 10), the following four questions are raised.

**Research Question 1: What are the relationships between cognitive representations and spatial configuration?**

The first question focuses on investigating the relationships between two physical elements represented in cognitive maps (i.e., landmarks and paths) and spatial configuration. This question involves the following:

**Sub-question 1A:** What are the relationships between landmarks and syntactic properties of spatial configuration (i.e., global integration, local integration, and connectivity)?

**Sub-question 1B:** What are the relationships between paths and syntactic properties of spatial configuration (i.e., global integration, local integration, and connectivity)?

Regarding the first set of questions, additional question (question 2) will explore the differences in people’s spatial cognition based on the degree of intelligibility of the neighborhood:

**Research Question 2: What is the role of intelligibility in spatial cognition?**

This question includes the two sub-questions as follows:

**Sub-question 2A:** Are there differences in cognitive representations (i.e., landmarks and paths) based on the intelligibility of the neighborhoods?

**Sub-question 2B:** Are there differences in relationships between cognitive representations (i.e., landmarks and paths) and syntactical measures based on the degree of intelligibility?
Research Question 3: What is the effect of spatial configuration as measured by intelligibility on perceived legibility of the neighborhoods?

This question focuses on investigating the effect of intelligibility on perceived legibility. The hypothesis is that the more intelligible an area is, measured by Space Syntax as objective value of spatial configuration, the more legibly it is reflected in a human’s spatial cognition.

Research Question 4: What are the differences in cognitive representations between people who are familiar with the urban environment and those who are unfamiliar with it?

This question focuses on comparing the cognitive representations of familiar people, (i.e., residents of the neighborhoods) and those of unfamiliar people (i.e., “newcomers” or “novices”).

3.3 DEFINITIONS OF TERMS

3.3.1 Spatial Configuration --- Objective Evaluation

Spatial configuration is defined as spatial relations taking into account other relations (Hiller, 1996, p. 1). It is the topological relationship between one space to the other spaces. Based on the theory of space syntax, four syntactic properties objectively describe and measure the spatial configuration.

1). INTEGRATION. Integration of a line is defined as a value that indicates the degree to which a line is more integrated, or segregated, from a system as a whole. Integration could be a global property if the relationships of a space/line to all other spaces/lines are taken into account. Or it may be a local property if only the relationships with spaces/lines in the vicinity are being considered.
**Global Integration**  Integration is a global measure (Rn) if the calculation of integration is based on the total depth from the current space. That is the relationships between each line to all other lines in the system are considered. The global integration is calculated as follows:

Step 1: \( \text{MD} = \frac{\text{TD}}{(N-1)} \)

Step 2: \( \text{RA} = 2(\text{MD}-1)/ N-2 \)

Step 3: \( \text{RRA} = \frac{\text{RA}}{DN} \)

Step 4: \( \text{GI} = \frac{1}{\text{RRA}} \)

Notation: MD: mean depth; TD: total depth; N: the number of axial lines; RA: relative asymmetry; RRA: real relative asymmetry; DN= D-value, the comparison of RA values with a diamond shaped pattern (justified map); GI: global integration.

First, the mean depth (MD) is calculated by total depth divided by the number of axial line minus one. Second, the relative asymmetry (RA) is obtained by using MD based on the formula. Generally, integration is calculated by the reciprocal value of relative asymmetric (RA). Since the number of axial lines is considered, this means that the system of the size can have an effect on RA values. So, to compare between different sizes of the system (e.g., large city and small city), RRA is used to mediate it. DN is the D-value of the system with the same number of spaces as the real system. Therefore, the consideration of RRA value gives us an opportunity to compare different sizes of cities and neighborhoods (Hiller and Hanson, 1984).

**Local Integration**  If a variable depth, instead of all depth, is considered, then the integration is called local integration. The calculation of this value is similar to the calculation of global integration, except that it considers lines that are up to n steps away. This is a local syntactic measure since it takes into account the streets in the immediate surrounding. In this study, local integration is calculated considering spaces/lines that are up to three steps away from a space/line of interest.
2). CONNECTIVITY. Connectivity is the measure of how well an axial line is intersected by others. In principle, there is no non-intersected line in any urban environment. Connectivity is a local measure since it only takes into account relationships between a space and its immediate neighbors. Thus, connectivity measures the degree of intersection or one step possibilities of each axial line (Hiller, 1996; Hiller and Hanson, 1984).

3). INTELLIGIBILITY. Intelligibility is defined as the degree to which what can be seen and experienced locally in the system allows the large-scale system to be learned without conscious effort (Hillier, 1996). In practice, the intelligibility value for an urban environment is calculated by the degree of linear correlation between connectivity and global integration values of the axial lines comparing the urban environment.

3.3.2 Spatial Cognition --- Subjective Evaluation

Spatial cognition is defined as the knowledge and internal or cognitive representations of the structure, entities, and relations of space (Hart and Moore, 1973). Based on the definition, spatial cognition includes two components: the physical elements (i.e., landmarks, paths, districts, nodes and edges), and the relations between them, which comprise cognitive representations or representations of cognitive maps. The product of spatial cognition is a cognitive map in his/her mind.

Cognitive Representations Cognitive representations are mental representations of the urban environment. They include five physical elements --- paths, landmarks, nodes, districts, edges --- and the relationships between them (Lynch, 1960). In this study, cognitive representations have the same meaning with cognitive maps. As in most of the previous studies (Lynch, 1960; Downs and Stea, 1973; Evans, 1984), cognitive representations will be measured by sketch maps in this study. Only two cognitive representations (i.e.,
landmarks and paths) will be examined. Landmarks and paths included in the sketch maps will be scored based on the frequency and degree of accuracy of the location in the sketch maps (for scoring details, see Section 4.1.5).

**Legibility**  
*Legibility* is defined as the ease with which part of an urban environment can be recognized and can be organized into a coherent pattern (Lynch, 1960). Based on this definition, the completeness and accuracy of sketch maps (identifying the physical elements of environment) and the accuracy of recognition tests (correctness of recognizing the pictures) will reflect the degree of perceived legibility of an urban environment (Cohen, 1980; Evans, 1984; Haq, 2003). In addition, perception of spatial cognition ability are also assessed.

Both cognitive representations and legibility are an individual’s subjective evaluations of the urban environment.

### 3.3.3 Personal Experiences

*Personal experiences* refers to humanistic and subjective experiences such as the interactive relations between an urban environment and individual (Appleyard, 1979, Yeung and Savage, 1996). Based on the literature review, personal experiences include five indicators relevant to an individual's spatial cognition: familiarity, travel mode, location of home, associativity, and socio-economic status (Appleyard, 1976, Evans, 1980). Familiarity is the connection between an individual and an urban environment. It is often indicated by the frequency he/she travels to some place or the length of residency in a neighborhood (Appleyard, 1979). In this study, the concept of familiarity is considered through the differences in the two samples (i.e., residents and newcomers to the neighborhoods as familiar and unfamiliar groups respectively).
CHAPTER 4: METHODOLOGY AND METHODS

In this study, four research questions are raised. The different nature of these four research questions requires use of a combined research strategy. To address the research questions, two research designs, correlational and experimental research designs, have been combined in this study. The advantage of such a design is that particular procedures and standards associated with each strategy can be presented fully and distinctively (Groat and Wang, 2001; Creswell, 1994). The research questions and associated research designs are shown in Figure 11.
Figure 11: Research Questions and Related Research Designs of the Study.

These two studies, the correlational and experimental, will be described separately in the following sections.

The study was conducted in a real field setting. Changsha, which is the capital city of the Hunan province in China, is the site for this investigation (Figure 12). The city of Changsha has over 2 million people with an area of 556 square kilometers. The global integration, local
integration, and connectivity of axial map in Changsha are shown in Figures 13, 14, and 15.

Figure 12: Aerial Photo of the City of Changsha. Source: Earth.google.com.
Figure 13: The Global Integration Map of Changsha.
Figure 14: The Local Integration Map of Changsha.
Figure 15: The Connectivity Map of Changsha.
4.1 STUDY 1 --- CORRELATIONAL RESEARCH

4.1.1 Research Design

To answering the first two research questions, a correlational study was conducted at an urban scale. According to Groat and Wang (2002), within the general framework of correlational research, two major subtypes can be identified: 1) relationship and 2) causal-comparative. Relationship studies focus on the natural and predicative power of relationships between variables. In this regard, the relationships between multi-level spatial configuration and cognitive representations (research question 1) can be answered by using a relationship study.

On the other hand, causal-comparative design focuses on causality that characterizes experimental research. The comparable groups of people or comparative physical environments are selected based on the research purpose. The purpose of selecting a comparable example is to reveal a “cause” for significant differences in the level of measured variables (Groat and Wang, 2002). Therefore, it is suitable to choose a causal-comparative study to investigate how the relationships between spatial configuration and cognitive representations are changed based on degree of intelligibility (research question 2). Figure 16 indicates the general research design of this correlational study and shows that spatial configuration of the two neighborhoods is objectively measured by Space Syntax. Dependent variables of human cognitive representations are measured by sketch maps and a semi-structured interview.
4.1.2 Study Area

In order to select the two neighborhoods, I developed the axial maps of Changsha and conducted syntactic analysis to calculate global integration, local integration, and connectivity measurements. After that, I searched for neighborhoods with different intelligibility.

Two neighborhoods within the city boundary, Rong-wan-zhen and Dong-pai-lou, have been chosen based on the criteria described in previous studies (Kim, 2001; Hiller, 1988, 1996). These two neighborhoods have a similar size (about 2 square kilometers), number of spaces (38 axial lines), building types (mixed with different building heights), and land uses (both having commercial, retail, residential, governmental uses, and so on). In addition, both
neighborhoods are located at the either side of the Bridge of Ju-zhi-zhou and are not far away from each other (Figures 17a and b and Figures 18 a and b).

Figure 17a: Aerial Photo of the Rong-wan-zhen Neighborhood. Source: Earth.google.com.
Figure 17b: Aerial Photo of the Dong-pai-lou Neighborhood. Source: Earth.google.com.
Figure 18a: The Road Layout of the Rong-wan-zhen Neighborhood.
Figure 18b: The Road Layout of the Dong-pai-lou Neighborhood.
Syntactic characteristics of the study neighborhoods and Changsha are summarized in Table 3.

<table>
<thead>
<tr>
<th></th>
<th>Changsha</th>
<th>Dong-pai-lou (D)</th>
<th>Rong-wan-zhen (R)</th>
<th>P (D&amp;R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Spaces (axial lines)</td>
<td>1444</td>
<td>38</td>
<td>38</td>
<td>NA</td>
</tr>
<tr>
<td>Mean Global Integration</td>
<td>1.04</td>
<td>1.39 (0.16)</td>
<td>1.19 (0.14)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean Local Integration</td>
<td>1.79</td>
<td>2.76 (0.70)</td>
<td>1.77 (0.51)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean Connectivity</td>
<td>3.45</td>
<td>7.45 (8.99)</td>
<td>3.47 (2.32)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intelligibility (Rn and Connect., R²)</td>
<td>0.18</td>
<td>0.58</td>
<td>0.37</td>
<td>NA</td>
</tr>
</tbody>
</table>

Note: Standard deviation in parenthesis

As Table 3 shows, the Dong-pai-lou neighborhood has much larger mean global integration, mean local integration, and mean connectivity values than that of the Rong-wan-zhen neighborhood. More importantly, its intelligibility value is also much larger than Rong-wan-zhen (0.58 for Dong-pai-lou vs. 0.37 for Rong-wan-zhen). This indicates a much clearer relationship between global and local structures in the Dong-pai-lou neighborhood. It is expected that these relationships make it easier for people to understand the global structure of neighborhood based on the local information or structures, when moving around the area. In contrast, the unstructured complexity and less hierarchical spaces (having smaller standard deviations for integration and connectivity values) in Rong-wan-zhen have the effect of making the system, as a whole, unintelligible as shown. Overall, this comparative analysis identifies that the Dong-pai-lou neighborhood is more intelligible than that of the Rong-wan-zhen neighborhood. It is assumed that this clear difference in
intelligibility as independent variables will affect a human’s spatial cognition.

4.1.3 Sample Selection

In this part of the study, 67 residents living in the two neighborhoods were conveniently selected to draw a sketch map of the neighborhoods. Convenient sampling is used in this study because of difficulties in conducting random sampling in a Chinese context. However, in order to allow for comparison across the neighborhoods and two different groups, familiar and unfamiliar groups, respondents in these two neighborhoods were selected based on gender and age quotas (range from 20 to 30 years old). The researcher and assistants found the respondents based on judgment according to the quota criteria. In realizing the difficulty the respondents might have in carrying out a formal interview and the advantage of obtaining richer information from formal interviews, the interviews were performed in public spaces in the neighborhoods.

4.1.4 Data Collection

Twelve assistants (nine students and three instructors from the Central South University Department of Architecture) helped in data collection. They were trained for two days. On the first day, they were instructed on the process of interviewing residents based on the developed script. On the second day, the assistants went to the neighborhoods to interview the residents as a pilot study. The actual data collection took place during a two week period in November 2006. The twelve assistants were divided into six groups. Each group consisted of two people, one female and one male. Each group searched for the appropriate residents in the neighborhood and asked them to draw a sketch map of their neighborhood following a short interview. Before sketch map drawings and interviews, each respondent was asked to sign the consent letter, which was approved by the NCSU Institutional Review
Board (IRB) in October 2006. After the interview, each respondent was given 10 Chinese Yuan (1 US dollar) as compensation.

Space Syntax Measurements

Space Syntax has been utilized to measure the syntactic characteristics of spatial configuration of Changsha city. As mentioned earlier, integration values (global and local), connectivity, and intelligibility are independent variables that objectively measure spatial configuration. The syntactic measurements in the two neighborhoods are calculated based on the whole urban area, not only the neighborhoods.

Sketch Maps and Semi-structured Interviews

For measuring cognitive representations, respondents were asked to draw and label the sketch maps of the neighborhood, including streets and buildings. The interviewee was instructed that the purpose of the sketch map is as a guide for a visitor to orient himself/herself and to find his/her way in the neighborhood. In order to set a uniform scale and orientation to the map following the methodology used by Kim (2001), the Bridge of Ju-zhi-zhou and Xiang River were marked on a blank A4 sized paper (Appendix 1). A sample of sketch maps developed by residents in the two neighborhoods are shown in Figures 19a and b.

After the respondent finished his/her sketch map, based on what he/she drew, the interviewer asked the respondent several open-ended questions, which were already used by Lynch (1960) and Cohen (1980) (Appendix 2). However, they were modified to fit the purpose of the study. These open ended questions focused on: 1) why residents remember and draw certain roads and buildings in the paper, rather than the others and 2) what are the
features of the buildings and roads that make them unforgettable in their mind. After that, the respondent’s socio-demographic information was collected. For each participant, half an hour was allotted for the sketch map and interview.
Figure 19a: Sketch Maps of the Dong-pai-lou Neighborhood from Residents
Figure 19b: Sketch Maps of Rong-wan-zhen Neighborhood from Residents
Identifying Building Characteristics

To fully and better understand physical features of landmarks, the landmarks (i.e., buildings) that appeared in residents’ sketch maps were photographed and their characteristics were scored as objective measurements. Those building characteristics include distinctiveness, function, historical meaning, and maintenance (Appendix 3).

4.1.5 Data Analysis

To analyze the sketch maps, cognitive representations (i.e., landmarks and paths) reflected in sketch maps were encoded. The unit of analysis was either cognitive representations (i.e., landmarks and paths) or individuals (residents). Based on the sketch maps collected from the respondents, there were a number of typical errors/distortions in their sketch maps, which include incompleteness, variations in scale across the area, roads being drawn too wide or narrow, possible straightening and orthogonalization of roads, and landmarks being drawn beyond the correct location. Therefore, two ordinal scales, one for landmarks and one for roads/parks, were developed for measuring the accuracy and frequency of cognitive representations.

Based on the previous studies (Kim, 2001) and actual distortions/errors on the collected sketch maps, an ordinal scale was developed to score the buildings drawn in respondents’ sketch maps (Figure 20). If buildings were correctly drawn and labeled by the respondent, they were encoded with a score of “3”; if buildings were partly correctly drawn (still along the right road/street) and correctly labeled, they were encoded with a score of “2”; if buildings are incorrectly drawn (being drawn along the wrong road) and correctly labeled, they were encoded with a score of “1”; if buildings did not exist on the sketch map, they were encoded with a score of “0”. The overall scoring system was developed to take into account the
locational accuracy of landmark buildings in sketch maps. Each building was also assigned syntactic measurements based on its correct location in relation to the actual axial map of the neighborhood by using Geographic Information System (GIS).

As for streets/paths, another ordinal scale was developed to score the paths that appeared in respondents’ sketch maps. If roads/streets were correctly drawn and labeled by the respondent on the sketch maps, they were encoded with a score of “5”; if roads/streets were correctly drawn and not being labeled or wrongly labeled, they were encoded with a score of “4”; if roads/streets were drawn partly correctly (distortions in width, curve, and angle) and correctly labeled, they were encoded with a score of “3”; if the roads/streets were drawn partly correctly and not being labeled or wrongly labeled, they were encoded with a score of “2”; if roads/streets are incorrectly drawn (wrong location or direction) and correctly labeled, they are encoded as score of “1”; and if roads/streets did not exist on the sketch map, they were encoded with a score of “0”. Each street/road was also assigned syntactic measurements based on its correct location in relation to the actual axial map of the neighborhood.

On the other hand, it is possible that individuals may correctly or partly correctly draw a road, but have difficulty remembering the name of the road. To fully consider this situation, a second scoring system that does not consider the labeling, but only takes into consideration the spatial aspects of the drawn roads was developed. Those two scoring systems are shown in Figure 21.

Based on the two ordinal scales mentioned above, landmarks and paths that were included in sketch maps were measured as landmark scores and path scores, which reflect the frequency and degree of accuracy of landmarks/paths in sketch maps.
Correctly drawn and correctly labeled
Encoded as "3"

Partly correctly drawn and correctly labeled
Encoded as "2"

Incorrectly drawn and correctly labeled
Encoded as "1"

Not drawn on sketch map
Encoded as "0"

Figure 20: Encoding System for Buildings
Figure 21: Encoding system for paths
The sketch maps were used to quantitatively analyze respondents’ cognitive representations of the neighborhood. The measurements included landmark scores and path scores. The results of the interviews were interpreted qualitatively. The relationships between spatial configuration and cognitive representations (research question one) were addressed by analyzing the relationship between syntactical parameters and the data from the sketch maps of the two neighborhoods. In addition, landmarks (buildings) were scored based on function (mixed-uses, commercial/retail uses, and single use except commercial and retail); historical meaning (high, medium, and low); distinctiveness to the background (strong, fair, and low); and maintenance of the building (good, fair, and bad) (Appleyard, 1969; Ewing, 2005). Actual photographs of the buildings and site observations (Figures 22 a, b, c, d) were utilized to scoring building characteristics. This was done so that a regression model could be used to analyze the relationships between landmark scores, syntactical parameters, and building characteristics. The protocols for measuring building characteristics are shown in Appendix 3.

![Figure 22a: Building Uses: Mixed-uses, Only Commercial or Retail Uses, and Single Use Except Commercial and Retail (from left to right).](image-url)
Research question two, the role of intelligibility in spatial cognition, was addressed by comparing the absolute values of bivariate correlations and multiple regression coefficients between syntactical parameters and the data from the sketch maps across the two neighborhoods and by comparing the respondents’ landmark scores and path scores between the two neighborhoods. Statistical significance tests for comparing model outputs for different samples was not considered since the comparison of standardized coefficients
such as correlations ($r$) and regression ($R^2$) between the models is not meaningful because they depend on the variances within the samples (Davidson and Mackinnon, 1982).
4.2 STUDY 2 --- EXPERIMENTAL RESEARCH

4.2.1 Research Design

The general purpose of an experimental design is to enable the researcher to credibly establish a cause-effect relationship. In this regard, the experimental research is seeking to ascertain and measure the extent to which a treatment causes a clearly measured outcome within a specified research setting, whether in a laboratory or in the field. To establish a cause-effect relationship, the characteristics of an experimental research design include the following: the use of treatment or independent variable; the measurement of an outcome or dependent variables; a clear unit assignment (to the treatment); the use of a comparison (or control) group; and a focus on causality (Groat and Wang, 2002). Therefore, to answer the third research question, which examines how intelligibility of the neighborhood affects residents' legibility, an experimental research design has been utilized (Figure 23).

The same two neighborhoods used in the correlational study were the sites for the experimental research. Except for a significant difference in intelligibility values measured by Space Syntax, the other variables are more or less comparable in these two neighborhoods. As mentioned previously, these two neighborhoods have similar size, density, number of paths, building types, and land uses. The difference between the two neighborhoods rests primarily on the intelligibility of the structure: one of the neighborhoods has higher intelligibility than the other (i.e., 0.58 vs. 0.37), which is the treatment in this study.

Two comparable groups participated in the study. Before the experiment, participants in the groups gathered in a public space of the neighborhood. The researcher verbally and in writing instructed the participants about the boundaries of the neighborhoods (street names) and let them explore the neighborhood freely for one hour. Each group traveled through only
one of the two neighborhoods (i.e., intelligible or less intelligible) and the traveling time was the same for both groups. After traveling, participants returned to the open place. Sketch maps, recognition tests, and post-experimental questionnaires were conducted with participants to measure the degree of perceived legibility of the neighborhoods. Figure 23 shows the research design of the second study.

4.2.2 Sample Selection and Randomization

In this experimental study, 49 voluntary students from the Central South University in Changsha, China were selected. Half of the voluntary students were recruited by posters displayed in the campus and the rest of them were recruited from the Department of Mechanical Engineering. None of student participants had visited either the Rong-wan-zhen or the Dong-pai-lou neighborhood nine months prior to the experiment. The participants
were first matched based on the spatial/visual ability testing scores (Ekstrom et al., 1976) and gender. Second, for those having the same gender and spatial ability test scores, they were randomly assigned to two groups. Each participant’s spatial/visual ability testing scores consisted of the number of correctly answered questions minus a fraction of the number answered incorrectly. Therefore, the range of scores was from –20 to 20 (Appendix 4).

4.2.3 Data Collection

Six assistants were involved in data collection. They were trained for one day during which they were taught the techniques and strategies about how to interview the student participants based on the script. The actual data collection was conducted on four weekdays in December 2006. Student participants were asked to sign the consent letter prior to the experiment. Each participant was given 10 Chinese Yuan (1 US dollar) for attending the experiment.

First, the student participants were asked to freely explore the neighborhood for an hour based on the pilot study conducted in July 2006 (an hour was enough for each participant to travel the whole neighborhood). To remind each participant about the boundary of the neighborhood during his/her exploration and to ensure that they would stay within the limits of the neighborhood, each participant was given a note that had street names as boundaries on it. Second, each individual was asked to draw the sketch map of the neighborhood. Third, a recognition test was conducted. Finally, the post-experimental interview was processed.

Sketch Maps

Following exploration, each student was asked to draw a sketch map of the neighborhood (the unforgettable roads/streets and buildings in the neighborhood). Also, if they could
remember the names of streets/buildings, they were allowed to write them down on the sketch maps. In order to set a uniform scale and orientation, the Bridge of Ju-zhi-zhou and Xiang River were marked on a blank A4 sized papers (Appendix 5). This stage lasted about fifteen minutes. Examples of sketch maps from students in the two neighborhoods are shown in Figures 24a and b.
Figure 24a: Sketch Maps of the Dong-pai-lou Neighborhood from Students.
Figure 24b: Sketch Maps of the Rong-wan-zhen Neighborhood from Students
Recognition Tests

Besides the sketch maps for testing legibility, the recognition test developed by Cohen (1980) and Evans et al. (1984) was also used in this study. Twelve scenes along routes with high, medium, and low integration values in each neighborhood were photographed before the experiment began. The photographed scenes included the intersections and midway points between two blocks on predefined routes. In addition, four other scenes outside the neighborhood were included in the test. In total, sixteen scenes were included in the recognition tests (Appendix 6 and Appendix 7). These scenes were printed in high-resolution color images on A4 sized paper. After drawing the sketch map, each respondent was asked to locate each picture in the real map of the neighborhood. Each participant was given ten minutes for the test.

Post-experimental Interviews

The post-experimental interview was carried out after the recognition tests. The interview was designed to inquire about the students' feelings regarding difficulties encountered navigating the two neighborhoods as shown in Appendix 8. The items included in the interview were based on the questionnaire from Weisman's wayfinding study (1981). However, they were modified and simplified according to the research purpose of this study. In particular, the respondent was asked: 1) the degree of difficulty for drawing the sketch map of the neighborhood; 2) the degree of confidence about accuracy of the sketch map; and 3) the degree of confidence about giving directions to a stranger. The interview lasted about ten minutes.
4.2.4 Data Analysis

For sketch maps, the unit of analysis was either cognitive representations (i.e., landmarks and paths) or individuals (students). Based on actual data collected from student participants, most participants labeled the buildings and streets on the sketch maps, although it was not required to do. Therefore, the same encoding systems for paths and landmarks mentioned in the correlational study (Figures 20 and 21) were also utilized to measure the accuracy of the sketch maps of the student participants.

Regarding the recognition tests, an ordinal scale was developed to measure the correctness of photo locations. If the scene was correctly located, it was encoded as “2”; if the scene was partly correctly located, which means it was still along the right road between the two blocks or around the intersection but beyond the right location, it was encoded as “1”; if the scene was located in the wrong place, it was encoded as “0”.

The answers to the questions in the post-experimental interview were assigned an ordinal (range from -4 to 4) and category scale (Yes, Fair, No). For the recognition test, each participant’s score of locating the photos was recorded. After that, the respondents’ sketch maps, recognition tests, and post-experimental questionnaires were analyzed to compare the neighborhoods legibility.

The last research question, the differences in cognitive representations between the people who are familiar with the environment and those who are unfamiliar with it, was analyzed by comparing absolute values of bivariate correlations and multiple regression coefficients obtained from the sketch maps drawn by residents that participated in the relationship study and by students that participated in the experimental study (i.e., the relationships between syntactical parameters and the data from the sketch maps).
4.3 RESEARCH METHODOLOGY --- SUMMARY

According to the conceptual models, research designs, and methodology discussed previously, the overall scheme of the study concepts, indicators, measurements, and data analysis utilized in this study are shown in Table 4.
<table>
<thead>
<tr>
<th>CONCEPTS</th>
<th>INDICATORS</th>
<th>METHODS OF DATA COLLECTION</th>
<th>MEASUREMENTS</th>
<th>DATA ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Cognition (Subjective evaluation)</td>
<td>Cognitive representation, Physical elements, Landmarks</td>
<td>- Sketch maps, - Interview</td>
<td>- Sketch maps --- Streets/paths: ordinal encoded, - Interview: qualitative</td>
<td>- Unit analysis: paths &amp; landmarks or individuals, - Bivariate correlation; multiple regression analysis (landmark/path scores, syntactical measures and building characteristics), - Landmark/path scores</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical elements, Landmarks</td>
<td>- Sketch maps, - Interview</td>
<td>- Sketch maps --- Buildings: ordinal encoded, - Interview: qualitative</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical elements &amp; Relations</td>
<td>- Sketch maps, - Recognition tests, - Post-experimental interviews</td>
<td>- Sketch maps --- Paths/landmarks: ordinal encoded, - Recognition tests: correctness of scene recognition in real map, - Post-experimental interview: ordinal/categorical scale</td>
<td>- Unit analysis: individuals, - Mean landmark/path scores, - Scores of scene recognition, - T-test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spatial Configuration (Objective evaluation)</td>
<td>Syntactic properties</td>
<td>- Space Syntax analysis</td>
<td>- Ratio scale</td>
<td>- Syntactic parameters for each axial line</td>
</tr>
<tr>
<td></td>
<td>- Global Integration, local integration, connectivity, intelligibility, - Intelligibility</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.4 QUALITY CONSIDERATIONS OF THE STUDY

4.4.1 Internal Validity

The fundamental issue of internal validity is whether the key concepts and operations of the study are truthful representations of the object of the study (Groat and Wang, 2002). To make sure that the methods and measurements in this study are the true operations of the concepts in the model in a Chinese context, two pilot studies were conducted in July 2006 and November 2006.

Another more important issue in internal validity is whether the results of the differences in human spatial cognition between the two neighborhoods could be attributed to their different spatial configurations measured by Space Syntax. This goal was achieved by carefully selecting two comparable neighborhoods with similar characteristics, and choosing comparable respondents/participants as samples. Except for a significant difference in intelligibility values measured by Space Syntax, the other social and physical variables, which may affect human spatial cognition, were more or less comparable in these two neighborhoods. The student participants had not visited one of the two neighborhoods nine months prior to the study and were matched based on spatial ability tests/batch randomization (Ekstrom et al., 1976) across the two neighborhoods. For residents, gender and age quotas were used to ensure comparability across the respondents of the two neighborhoods.

4.3.3 Construct Validity

Construct validation focuses on assessing the validity of the measurements. The core of construct validity is whether the measurements actually measure what they should measure.
As Carmines and ZellerIn (1979) pointed out, construct validation involves three distinctive steps: first, specifying theoretical relationships between concepts; secondly, examining relationships between measures of concepts; and thirdly, interpreting evidence in terms of how it clarifies the construct validity of particular measures.

In this study, a great deal of literature review of previous studies on spatial cognition, legibility, wayfinding, and Space Syntax was conducted to create the conceptual model of this study. The proposed conceptual model clearly and accurately defines what would constitute human spatial cognition, cognitive maps, cognitive representations, and includes a rationale for the correspondence from the concept definitions to methods and measurements as shown in Table 4.

In addition to sketch maps as the main approach to investigate cognitive representations and legibility, by conducting semi-structured interviews and recognition tests and post-experimental interview with student participants, the study provides a comprehensive image of individual’s human spatial cognition.

### 4.3.4 Reliability

The concept of reliability is concerned with the consistency of the measurements or findings. The assumption is that the research methods would yield the same results if the study was conducted under the same conditions at another location or time (Groat and Wang, 2002).

In this study, the reliability of instruments is of most concern. To achieve this goal, first, most of the measurements/instruments adopted in this study have been used successfully in previous studies. Additionally, pilot studies were conducted before final data collection to make sure that the instruments were clearly and correctly understood by participants in a
Chinese context. Second, since the reliability of scoring the sketch map is a concern in this study, the previous studies on how to encode the sketch maps qualitatively and quantitatively were reviewed (Lynch, 1960; Cohen, 1980; Wiseman, 1981; Evans et al., 1984; Kim, 2001) and then a systematic encoding criterion for sketch maps was developed. In addition, two independent raters (the researcher and an assistant) judged the sketch maps based on the developed encoding systems. Interrater reliability for sketch maps and objective physical features of landmarks were calculated by using a Pearson product moment (Boyatzis, 1998). The interrater reliability for landmarks is 0.91 and 0.85 for paths, and 0.89 for objective characteristic scoring of landmarks.

4.3.5 External Validity (Generalizability)

The question behind external validity is whether the results of the study are applicable to the larger world or other places, or at least whether there are defining contextual constraints within which the results are valid (Groat and Wang, 2002). To ensure the results of the study contribute not only to the overall physical environment in China, but also is a benefit to other Asian countries, a middle-size city, Changsha in China, was chosen as the study area. According to State Statistical Bureau (2002), middle-scale cities comprise 62% of the cities in China by 2002. In addition, similar with the other cities in Eastern Asia, the city of Changsha also has the two characteristics: a high-density land use pattern with a large population; and the mixed-use neighborhoods within walking distance. The similar urban characteristics between Chinese cities and other Eastern Asian cities make the external generalization of this study more wide and meaningful.

According to Yin (1994), the case study’s strength is its capacity to generalize to theory, much in the way a single “experiment” can be generalized to theory by being tested through other experiments. In this study, both a causal-comparative case study and an experiment
have been adopted, so that if the results of the correlational and experimental studies support the hypotheses raised in the conceptual model, the results of this study can be generalized to theory.
CHAPTER 5: DATA ANALYSES AND RESULTS

This chapter includes six sections. The first section will discuss the characteristics of the samples in this study. The second will present the results of syntactical properties of the two neighborhoods. The remaining four sections will discuss the results of data analysis arranged by the four research questions that this study aims to answer.

5.1 SAMPLE CHARACTERISTICS

In this section, the sample characteristics of the two studies, correlational research and experimental research, will be discussed respectively.

5.1.1 Correlational Research

In the first study, a total of 67 residents were interviewed in the two neighborhoods, 35 residents in the Rong-wan-zhen neighborhood and 32 residents in the Dong-pai-lou neighborhood. Two residents in the Rong-wan-zhen neighborhood had difficulties or were reluctant to draw the sketch maps. However, they were able to talk in detail about the streets and buildings in the neighborhood. Therefore, the assistants drew the sketch maps based on what the two residents described. To eliminate the inconsistency in data, these two residents were not included in the sample. Thus, the final sample included a total of 65 residents. The respondents’ socio-demographic information in the two neighborhoods is summarized in Table 5.
Table 5: Socio-demographic Information for Residents.

<table>
<thead>
<tr>
<th></th>
<th>Dong-pai-lou (High Intelligibility)</th>
<th>Rong-wan-zhen (Low Intelligibility)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>32</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>22 (69%)*</td>
<td>18 (55%)*</td>
<td>0.131</td>
</tr>
<tr>
<td>Female</td>
<td>10 (31%)*</td>
<td>15 (45%)*</td>
<td>0.131</td>
</tr>
<tr>
<td>Age (Years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (Min.- Max.)</td>
<td>19 - 34</td>
<td>19 - 35</td>
<td>NA</td>
</tr>
<tr>
<td>Mean</td>
<td>27.94 (4.37)**</td>
<td>26.12 (4.85)**</td>
<td>0.124</td>
</tr>
<tr>
<td>Length of Residence (Years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (Min.- Max.)</td>
<td>0.5 - 33.0</td>
<td>0.5 - 25.0</td>
<td>NA</td>
</tr>
<tr>
<td>Mean</td>
<td>11.69 (9.29)**</td>
<td>9.39 (7.26)**</td>
<td>0.271</td>
</tr>
</tbody>
</table>

*: Percentage in parentheses
**: Standard deviation in parentheses

Table 5 shows that there is not a significant difference in the mean age and length of the residence between the two neighborhoods since their p values are higher than 0.05. While Rong-wang-zhen neighborhood has a higher percentage of female respondents than Dong-pai-lou (i.e., 45% vs. 31%), a Z test revealed that this difference is not significant (p=0.131). Overall, the comparison of socio-demographic characteristics between the two neighborhoods has indicated that the two resident groups are comparable, especially in gender, mean age, and length of residence.
5.1.2 Experimental Research

A total of 49 students participated in the field experiment. Of the 49 students, one student traveled outside the indicated boundaries and was excluded from the final sample. The final valid data set, which included sketch maps, recognition tests, and post-experimental interviews, included 48 responses. The percentage of students coming from a mechanical engineering department was 44% in the Dong-pai-lou neighborhood and 57% in Rong-wan-zhen. A Fisher’s Exact test (Agresti and Finlay, 1997) revealed that the percentage of students coming from a mechanical engineering department between the two neighborhoods is insignificant (p=0.558). The student participants’ socio-demographic information and spatial ability test scores are summarized in Table 6.
Table 6: Socio-demographic and Test Score Information for Students.

<table>
<thead>
<tr>
<th></th>
<th>Dong-pai-lou (High Intelligibility)</th>
<th>Rong-wan-zhen (Low Intelligibility)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=25</td>
<td>N=23</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>18 (72%)*</td>
<td>14 (61%)*</td>
<td>0.541</td>
</tr>
<tr>
<td>Female</td>
<td>7 (28%)*</td>
<td>9 (39%)*</td>
<td>0.541</td>
</tr>
<tr>
<td>Age (Years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (Min.- Max.)</td>
<td>19 - 24</td>
<td>19 - 24</td>
<td>NA</td>
</tr>
<tr>
<td>Mean</td>
<td>20.48 (1.05)**</td>
<td>20.69 (1.40)**</td>
<td>0.548</td>
</tr>
<tr>
<td>Score of Spatial Ability Test***</td>
<td>2 - 20</td>
<td>-2 - 20</td>
<td>NA</td>
</tr>
<tr>
<td>Mean</td>
<td>15.84 (4.72)**</td>
<td>14.86 (5.49)**</td>
<td>0.512</td>
</tr>
</tbody>
</table>

*: Percentage in parentheses  
**: Standard deviation in parentheses  
***: The range of spatial ability test scores for each question is from -20 to 20 for a total of 20 questions

As Table 6 shows, the two student groups are comparable in gender, mean age, and mean score of spatial ability since the p values for all these variables are higher than 0.05.

5.2 SYNTACTIC CHARACTERISTICS OF THE TWO NEIGHBORHOODS

The Dong-pai-lou neighborhood is located on the eastern side and the Rong-wan-zhen neighborhood is located on the western side of the Xiang River in Changsha. The two neighborhoods are not far from each other. Compared to Rong-wan-zhen, Dong-pai-lou is closer to the downtown of Changsha City. Dong-pai-lou is bounded by Wu-yi Blvd to the
north, Jie-fang Road to the south, Ca-e road to the east, and Xiang River Blvd to the west. The size of the Dong-pai-lou neighborhood is approximately 2 square kilometers. The Rong-wan-zhen neighborhood is bounded by a tributary of the Western Lake to the north, Xin-min Road to the south, Xiao-xiang Blvd to the east, and Feng-lin-er Road to the west. The size of the area is also approximately 2 square kilometers.

Figures 25, 26, and 27 show the global integration, local integration, and connectivity maps of the two neighborhoods. In the maps, the lines are represented from dark red color to light blue, which represents the degree of integration of axial lines. The dark red lines are most integrated (i.e., they are syntactically the most accessible lines within the system). On average, these lines could be accessed within the fewest changes in direction from all the other lines. From Figures 25 and 26, it is noted that the Dong-pai-lou neighborhood has more high integration lines than the Rong-wan-zhen neighborhood, which makes a highly sprawled and interconnected network. By contrast, only several high integration lines comprise the interconnected network in the Rong-wan-zhen neighborhood. Also, the Rong-wan-zhen neighborhood has more cul-de-sacs with low integration values than Dong-pai-lou. In addition, the structure of axial lines in the Dong-pai-lou neighborhood is different from that of Rong-wan-zhen. The Dong-pai-lou neighborhood has a clearer grid network than Rong-wan-zhen.
Figure 25: The Global Integration Map of the Two Neighborhoods.
Figure 26: The Local Integration Map of the Two Neighborhoods.
Figure 27: The Connectivity Map of the Two Neighborhoods.
The overall syntactical characteristics and the comparison between the two neighborhoods are presented in Table 7. As Table 7 shows, the mean values of global integration, local integrations, and connectivity for the high intelligible neighborhood (Dong-pai-lou) are higher than that of the low intelligible neighborhood (Rong-wan-zhen).

<table>
<thead>
<tr>
<th></th>
<th>Dong-pai-lou (High Intelligibility)</th>
<th>Rong-wan-zhen (Low Intelligibility)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of axial lines</td>
<td>38</td>
<td>38</td>
<td>N/A</td>
</tr>
<tr>
<td>Mean Length (ft)</td>
<td>389.13</td>
<td>410.63</td>
<td>0.451</td>
</tr>
<tr>
<td>Global Integration</td>
<td>Mean 1.39</td>
<td>1.19</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Min. - Max. 1.12 - 1.89</td>
<td>0.96 - 1.66</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Range 0.77</td>
<td>0.70</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>SD 0.16</td>
<td>0.15</td>
<td>N/A</td>
</tr>
<tr>
<td>Local Integration</td>
<td>Mean 2.76</td>
<td>1.77</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Min. - Max. 1.35 - 4.11</td>
<td>0.68 - 3.11</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Range 2.76</td>
<td>2.43</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>SD 0.70</td>
<td>0.51</td>
<td>N/A</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Mean 7.45</td>
<td>3.47</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Min. - Max. 1 - 39</td>
<td>1 - 13</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Range 38</td>
<td>12</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>SD 8.99</td>
<td>2.32</td>
<td>N/A</td>
</tr>
<tr>
<td>Intelligibility</td>
<td>0.58</td>
<td>0.37</td>
<td>N/A</td>
</tr>
</tbody>
</table>
5.3 THE RELATIONSHIPS BETWEEN COGNITIVE REPRESENTATIONS AND SPATIAL CONFIGURATION

This section will present the results of the correlational study, which is aimed at examining the relationships between cognitive representations (i.e., landmarks and paths) and spatial configuration as measured by Space Syntax. In particularly, this stage of the study examines the relationships between landmark/path scores and the three syntactical measures (global integration, local integration, and connectivity). This section includes three parts. The first part will focus on the relationships between landmark scores and the three syntactical measures and the second on the relationships between path scores and the three syntactical measures. Finally, a section summary will be developed based on the findings.

Figure 28 shows the landmarks and paths that have been included in all 65 sketch maps drawn by the residents of the two neighborhoods. The landmarks and paths have been encoded based on the procedure discussed in Section 4.1.5. The landmark scores and path scores indicate the frequency and accuracy of elements that were drawn by residents.
Figure 28: Landmarks and Paths Included in the Residents’ Sketch Maps Within the Two Neighborhoods.

Note: Landmark score and path score represent the frequency and accuracy of elements drawn in the sketch maps.
5.3.1 The Relationships between Landmark Score and Spatial Configuration for Residents

In this part, first, the results of residents' sketch map analyses will be presented and then the findings from the interviews will be described. Finally, analysis combining landmark scores, building characteristics, and syntactical measures will be introduced.

The Results of Residents' Sketch Map Analysis

There are 42 buildings in the residents' sketch maps within the two neighborhoods. The buildings are diversified in terms of their location, function, building height, color, and mass. Based on a previously developed coding system for landmarks (see Section 4.1.5), each building's total landmark score was calculated by taking into account the frequency and degree of locational accuracy of buildings drawn in the sketch maps (Figure 29). After that, each building was assigned three syntactical measures (i.e., global integration, local integration, and connectivity) of the nearest axial line by using spatial join procedure in Geographic Information System (Figure 30).
Figure 29: Landmark Buildings Included in the Residents’ Sketch Maps Within the Two Neighborhoods.

Note: Landmark score represents the frequency and locational accuracy of elements drawn in the sketch maps.
Figure 30: Overlay of Landmark Scores and Global Integration of the Two Neighborhoods (Residents).

Note: Landmark score represents the frequency and locational accuracy of elements drawn in the sketch maps.
To fully understand the relationships between landmark scores and the three syntactical measures (i.e., global integration, local integration, and connectivity), bivariate correlation analysis, bivariate regression analysis, and multiple regression analysis were performed.

A bivariate correlation analysis was utilized to understand the relationships between landmark scores and the three syntactical measures of the spatial configuration. As shown in Figure 31, global integration has the strongest and significant correlation with landmark score ($r=0.51$, $p=0.000$), followed by local integration. The correlation between landmark score and connectivity is very weak and insignificant ($p>0.05$).

<table>
<thead>
<tr>
<th>Global Integration</th>
<th>$r$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.51</td>
<td>0.000</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.26</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Local Integration (r)</th>
<th>$r$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.39</td>
<td>0.005</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.15</td>
<td>0.006</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connectivity (r)</th>
<th>$r$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.23</td>
<td>0.075</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.05</td>
<td>0.147</td>
</tr>
</tbody>
</table>

N= 42 landmarks

Figure 31: Correlation Coefficients and Scatterplots of the Relationships Between Landmark Scores and Three Syntactical Measures for Residents of the Two Neighborhoods.

Next, a bivariate regression analysis was conducted to examine the predictive power between the landmark score as a dependent variable and one of the three syntactical measures as independent variables. The results showed that global integration has the largest predictive power and it explains 26% ($p=0.000$) of the variation in landmark scores,
whereas local integration explains 15% (p=0.006). The predictive power between landmark score and connectivity is very weak and insignificant (p>0.05).

Multiple regression analysis was performed to examine the predictive power between the landmark score as a dependent variable and the three syntactical measures as independent variables. When all three independent variables were included in the tested models, a strong collinearity between global integration and local integration was detected (VIF>4). Thus, local integration was dropped from the model. Overall, the results of the regression analysis showed that even when the other two syntactical measures are included in the model, global integration is the only significant variable explaining the variation in landmark scores (Table 8). For the two neighborhoods together, global integration again explains 26% of the variation in landmark scores (R²=0.26, p=0.001).

Table 8: Regression of Landmark Scores on Global Integration and Connectivity for the Two Neighborhoods (residents).

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Integration</td>
<td>0.76</td>
<td>0.000</td>
</tr>
<tr>
<td>Connectivity</td>
<td>-0.35</td>
<td>0.087</td>
</tr>
</tbody>
</table>

R²=0.26, P=0.001, N=42 landmarks
Dependent variable: landmark score
Why Landmarks Are Recognized?

Following the sketch map exercise, residents were also interviewed about two major open-ended questions on landmark recognition. The first question focused on why residents remembered and drew certain buildings in the sketch maps; and the second question focused on the physical features of the remembered buildings.

The results showed (Table 9) that most of the reasons that residents remember buildings are certain physical features of the buildings. For example, a few characteristics that residents mentioned were old buildings with historical meaning, heights of the buildings, new buildings and function (commercial or retail uses), etc. In addition, some residents also talked about the associativity reasons for remembering certain buildings, i.e., “have ever been to those buildings for business or shopping” and “often walk through the streets with those buildings along the sides”.

Table 9: Reasons for Remembering Certain Buildings (Based on the Residents’ Responses).

<table>
<thead>
<tr>
<th>Reasons for remembering certain buildings</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of the buildings</td>
<td>26</td>
</tr>
<tr>
<td>Have ever been to/ often walk by those buildings</td>
<td>15</td>
</tr>
<tr>
<td>Doing business/shopping in those buildings</td>
<td>16</td>
</tr>
</tbody>
</table>

N=65 residents

When asked about the details of the physical features of the buildings they remembered, the most frequent feature that they mentioned is the distinctiveness of the buildings from their backgrounds. This included the height, color, and mass of the buildings that made them unforgettable and noticeable against the other buildings (Figure 32). Next is the historical
meaning of the buildings, which makes them famous. Examples include Li-fu-chun’s former residence and Jia-yi’s former residence (Figure 33).

Figure 32: The Distinctiveness of the Buildings Against the Background.

Figure 33: Li-fu-chun’s Former Residence and Jia-yi’s Former Residence.

In addition, the function of the buildings is one of the important features for the residents’ landmark recognition. Residents mentioned that buildings with mixed/commercial uses (Figure 34) such as shopping malls, retail shops, and hotels, are recognized as important landmark features. As for locations of the buildings, quite a few residents talked that
buildings situated along the major roads, the crossings of the roads, and visibility of the buildings as important factors. On the other hand, the maintenance of the buildings, such as buildings with clean and neat façades, and newly built buildings, is also an important feature. Besides those mentioned above, a few residents talked about the aesthetic reasons (beautiful and luxurious) and noticeable signage. The overall summary of the physical features of buildings indicated by residents’ response frequency is shown in Table 10 and Figure 35.

Figure 34: Mixed Uses/Commercial Uses of the Buildings.
Table 10: Physical Features of Buildings as Remembered by the Residents.

<table>
<thead>
<tr>
<th>Physical Features of Buildings</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distinctiveness (mass/height/color)</td>
<td>44</td>
</tr>
<tr>
<td>Historical meaning</td>
<td>20</td>
</tr>
<tr>
<td>Function (commercial and mixed uses)</td>
<td>23</td>
</tr>
<tr>
<td>Location</td>
<td>20</td>
</tr>
<tr>
<td>Maintenance</td>
<td>8</td>
</tr>
<tr>
<td>Aesthetic reasons (beautiful and luxurious)</td>
<td>6</td>
</tr>
<tr>
<td>Signage</td>
<td>2</td>
</tr>
</tbody>
</table>

N=65 residents

Figure 35: Histogram of Physical Features of Buildings as Remembered by the Residents.
The Relationships Between Landmark Scores, Building Characteristics, and Syntactical Measures for Residents

Based on the results of the interviews, residents indicated that the distinctiveness, historical meaning, function, and maintenance of the buildings are the most important features of buildings that they remembered and drew in the sketch maps. Previous research showed that building characteristics play an important role in landmark recognition (Appleyard, 1969; Evans, 1980). To take into account these characteristics of buildings in explaining landmark scores, first, the buildings drawn in sketch maps were scored based on the coding system described in Section 4.1.5. Then these building characteristic scores were included in the regression models. Table 11 shows a summary of building characteristics as coded based on the photographs that included the buildings identified by residents.

Table 11: Landmark Buildings Characteristics.

<table>
<thead>
<tr>
<th>Building Characteristics</th>
<th>Building Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High (3)</td>
</tr>
<tr>
<td>Distinctiveness (mass/height/color)</td>
<td>33.3%</td>
</tr>
<tr>
<td>Historical meaning</td>
<td>2.4%</td>
</tr>
<tr>
<td>Function (commercial and mixed uses)</td>
<td>26.2%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>26.2%</td>
</tr>
<tr>
<td>Total number of landmark buildings: 42</td>
<td></td>
</tr>
</tbody>
</table>

First, Pearson correlation coefficients for all variables in the model were calculated to understand the relationships between landmark scores and distinctiveness score, historical meaning score, function score, and maintenance score. As shown in Table 12, distinctiveness and maintenance scores have the strongest correlations with landmark scores (i.e., r=0.46, p<0.000 and r=0.45, p<0.000), and function score has medium
correlation with landmark scores (i.e., r=0.28, p<0.036). By contrast, historical meaning score has very weak and insignificant correlation with landmark score (i.e., r=0.01, p>0.05). The reason might be that there are not so many historical buildings in the two neighborhoods, which results in lack of variability in the historical meaning score.

Table 12: Correlation Matrix for Landmark Scores and Four Building Characteristics Scores.

<table>
<thead>
<tr>
<th></th>
<th>Landmark Score</th>
<th>Distinctiveness</th>
<th>Historical Meaning</th>
<th>Function</th>
<th>Maint.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark Score</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distinctiveness</td>
<td>0.46***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical Meaning</td>
<td>0.01</td>
<td>0.12</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>0.28*</td>
<td>0.30</td>
<td>-0.27</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.45***</td>
<td>0.39**</td>
<td>0.15</td>
<td>0.30*</td>
<td>1</td>
</tr>
</tbody>
</table>

*P<0.05; **P<0.01; ***P<0.001
N=42 landmarks

Second, a multiple regression analysis was performed to investigate the predictive power of four dimensions of building characteristics on landmark scores. In the tested model the landmark score was the dependent variable, and the four building characteristic scores were the independent variables.

As shown in Table 13, the results of the regression analysis indicated that distinctiveness and maintenance scores are the two significant independent variables explaining the variation in landmark scores. Overall, together they explain 30% of the variation in landmark scores (R²=0.30, p=0.002).
Table 13: Regression of Landmark Scores on Four Building Characteristic Scores (Distinctiveness, Historical Meaning, Function and Maintenance) for the Two Neighborhoods (Residents)

<table>
<thead>
<tr>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distinctiveness</td>
<td>0.34</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.32</td>
</tr>
<tr>
<td>Function</td>
<td>0.07</td>
</tr>
<tr>
<td>Historical Meaning</td>
<td>-0.06</td>
</tr>
</tbody>
</table>

R²=0.30, P=0.00, N=42 landmarks
Dependent variable: landmark score

To obtain a more comprehensive understanding of residents’ landmark recognition, in particular to more clearly understand the role of spatial configuration in landmark recognition, a second multiple regression analysis was conducted. The second model examined the relationships between the landmark scores as a dependent variable and the four building characteristic scores (i.e., distinctiveness, historical meaning, function, and maintenance of the building), and the three syntactical measures as independent variables.

First, Pearson correlation coefficients for all variables in the second model were calculated to understand the relationships between landmark scores, syntactical measures (i.e., global integration, local integration, and connectivity) and the scores for four dimensions of building characteristics. As shown in Table 14, global integration has the highest correlation with the landmark scores (r=0.51, p<0.000). The next higher correlations with the landmark scores are related to distinctiveness (r=0.46, p<0.000) and maintenance scores (r=0.45, p<0.000), followed by local integration (r=0.39, p<0.000).
Table 14: Correlation Matrix for Landmark Scores, Syntactical Measures, and Building Characteristic Scores.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark Score</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Integration</td>
<td>0.51**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Integration</td>
<td>0.39*</td>
<td>0.93***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connectivity</td>
<td>0.23</td>
<td>0.75***</td>
<td>0.73***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distinctiveness</td>
<td>0.46**</td>
<td>0.45**</td>
<td>0.32*</td>
<td>0.39*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical Meaning</td>
<td>0.01</td>
<td>0.01</td>
<td>0.06</td>
<td>-0.03</td>
<td>0.12</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>0.28*</td>
<td>0.62***</td>
<td>0.56**</td>
<td>0.62***</td>
<td>0.30*</td>
<td>-0.27*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.45**</td>
<td>0.46**</td>
<td>0.42**</td>
<td>0.39*</td>
<td>0.39*</td>
<td>0.15</td>
<td>0.30*</td>
<td>1</td>
</tr>
</tbody>
</table>

*P<0.05; **P<0.01; ***P<0.001

N=42 landmarks

From the matrix, it is noted that there are relatively strong associations between three syntactical measures and function of the buildings (i.e., r=0.62 for global integration, r=0.56 for local integration, and r=0.62 for connectivity). This indicates that the buildings with mixed and commercial uses tend to cluster along the roads with higher global integration, higher local integration, and higher connectivity (i.e., high global and high local syntactical accessibility).

Following the bivariate correlation analysis, a multiple regression analysis was performed. In the first tested model that included all the independent variables, a strong collinearity between global integration and local integration (VIF>4) was detected. Therefore, local integration was dropped from the model and a second model that excluded local integration
was performed. Overall, the results of the second regression analysis showed that global integration is the only significant variable explaining the variation in landmark scores (Table 15). For the two neighborhoods together, it explains 26% of the variation in landmark scores ($R^2=0.26$, $p=0.001$). While previous analysis indicated that building characteristic scores (distinctive and maintenance scores) explained 30% of the variation in landmark scores (see Table 13), when syntactical measures were included in the model, they all lost their significance and global integration was the only significant variable explaining variation in landmark scores.

In this regard, it is evident that global integration is the most important independent variable to account for the variation of landmark scores compared to the other two syntactical measures and the four building characteristic scores.

Table 15: Regression of Landmark Scores on Four Buildings Characteristic Scores (Distinctiveness, Historical Meaning, Function and Maintenance) and Two Syntactical Measures (Global Integration and Connectivity) for the Two Neighborhoods (Residents).

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Integration</strong></td>
<td>0.56</td>
<td>0.021</td>
</tr>
<tr>
<td><strong>Connectivity</strong></td>
<td>-0.40</td>
<td>0.060</td>
</tr>
<tr>
<td><strong>Distinctiveness</strong></td>
<td>0.25</td>
<td>0.100</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>-0.08</td>
<td>0.582</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>0.01</td>
<td>0.981</td>
</tr>
<tr>
<td><strong>Historical Meaning</strong></td>
<td>-0.26</td>
<td>0.091</td>
</tr>
</tbody>
</table>

$R^2=0.26$, $p=0.001$, $N=42$ landmarks
Dependent variable: landmark score
5.3.2 The Relationships between Path Scores and Spatial Configuration for Residents

In this section, first, the results of sketch maps will be presented and then, the results of the interviews will be described.

The Results of Residents’ Sketch Map Analysis

A total of 36 paths (roads/streets) were drawn in the residents’ sketch maps within the two neighborhoods. The paths drawn on the sketch maps were scored for frequency and degree of accuracy, based on the scoring system described on Section 4.1.5. The results of the path scores are shown in Figure 36. After that, the axial lines that comprise each path within the neighborhood boundary were selected by using a buffer procedure in GIS. Then, the mean value of syntactical measures (i.e., global integration, local integration, and connectivity) of axial lines covering each path was calculated and assigned to each path (Figure 37).
Figure 36: Paths Included in the Residents’ Sketch Maps Within the Two Neighborhoods.

Note: Path score represents the frequency and accuracy of elements drawn in the sketch maps.
Figure 37: Overlay of Path Scores and Global Integration of the Two Neighborhoods (Residents).
Note: Path score represents the frequency and accuracy of elements drawn in the sketch maps.
The relationships between path scores and the three syntactical measures (i.e., global integration, local integration, and connectivity) were explored by performing bivariate correlation analysis, bivariate regression analysis, and multiple regression analysis.

The results of bivariate correlation analysis (Figure 38) showed that all syntactical measures have strong relationships with path scores. As shown in Figure 38, connectivity has the strongest correlation with path scores ($r=0.70$, $p=0.000$), followed by global integration ($r=0.68$, $p=0.000$) and local integration ($r=0.67$, $p=0.000$).

<table>
<thead>
<tr>
<th>Global Integration</th>
<th>$P$</th>
<th>Local Integration</th>
<th>$P$</th>
<th>Connectivity</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r=0.68$</td>
<td>0.000</td>
<td>$r=0.67$</td>
<td>0.000</td>
<td>$r=0.70$</td>
<td>0.000</td>
</tr>
<tr>
<td>$R^2=0.46$</td>
<td>0.000</td>
<td>$R^2=0.45$</td>
<td>0.000</td>
<td>$R^2=0.49$</td>
<td>0.000</td>
</tr>
</tbody>
</table>

N=36 paths

Figure 38: Correlation Coefficients and Scatterplots of the Relationships Between Path Scores and Three Syntactical Measures for Residents of the Two Neighborhoods.

Next, a bivariate regression analysis was conducted to examine predictive power between the path score as a dependent variable and one of the three syntactical measures as independent variables. The results showed that connectivity is the strongest variable ($R^2=0.49$, $p=0.000$) explaining the variation in path scores, followed by global integration and
local integration (i.e., $R^2=0.46$, $p=0.000$ and $R^2=0.45$, $p=0.000$ respectively).

Finally, a multiple regression analysis was performed to examine the predictive power between the path score as a dependent variable and the three syntactical measures as independent variables. When all three independent variables were included in the tested models, a strong collinearity between global integration and local integration was detected ($VIF>4$). Thus, global integration was dropped from the model. Overall, the results of the regression analysis showed that local integration and connectivity are the two significant variables explaining the variation in path scores (Table 16). For the two neighborhoods together, local integration and connectivity explain 55% of the variation in path scores ($R^2=0.55$, $p=0.000$)

Table 16: Regression of Path Scores on Local Integration and Connectivity for the Two Neighborhoods (Residents).

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Integration</td>
<td>0.38</td>
<td>0.031</td>
</tr>
<tr>
<td>Connectivity</td>
<td>0.43</td>
<td>0.008</td>
</tr>
</tbody>
</table>

$R^2=0.55$, $P=0.000$, N=36 paths

Dependent variable: path score

It is possible that an individual is able to correctly draw a path with respect to the others without remembering the name of the path. Thus, to only focus on the role of spatial layout, paths in the residents’ sketch maps were recoded based on the previously developed coding system (see Section 4.1.5). In this coding system, path naming/labeling did not play a role in calculating path scores (i.e., scores represent only locational accuracy for paths). The results using recoded path scores showed that the relationships between path scores and the three syntactical measures do not change much. The bivariate correlations between
path scores and the three syntactical measures are 0.66 (p=0.000) for global integration, 0.62 (p=0.000) for local integration, and 0.65 (p=0.000) for connectivity. The multiple regression analysis also showed that local integration and connectivity are the two significant independent variables explaining the variation in path scores (R²=0.50, p=0.000). Overall, when the correct street labeling was excluded for path scores, local integration and connectivity explained 50% of the variation in path scores. This is slightly less than the value (i.e., R²=0.55) when the initial coding system was used.

Why Paths Are Recognized?

Two open-ended questions were asked to explore residents’ recognition of paths. One question asked residents why they remembered and drew certain streets/roads in the sketch maps, and another asked about the important physical features of the streets/roads that they drew in the sketch maps.

The answers to the first question are summarized in Table 17. As table shows, the most frequently mentioned reason is “often walk through those streets/roads”, which make them unforgettable in residents’ minds.

<table>
<thead>
<tr>
<th>Reasons for remembering streets drawn in sketch maps</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often walk through those streets</td>
<td>49</td>
</tr>
<tr>
<td>Live by those streets</td>
<td>15</td>
</tr>
<tr>
<td>Many commercial buildings along those streets</td>
<td>14</td>
</tr>
<tr>
<td>Major streets</td>
<td>13</td>
</tr>
</tbody>
</table>

N=65 residents
Some residents mentioned that they remembered and drew certain streets in the sketch maps because those streets are the major streets (artery roads) or many commercial buildings are located along those streets.

As for the second question, regarding the important physical features of paths drawn in the sketch maps (Table 18, Figure 39), the most frequently indicated feature is that these streets have a lot of commercial use buildings along either side. In addition, some residents mentioned that the streets with large width or long length tend to be easily remembered. On the other hand, carefully arranged landscapes on the both sides of the streets also make them unforgettable for path recognition. The other features such as historical buildings along the streets, pavements (well-preserved and beautiful), and dirty and noisy environment were also mentioned by residents.

<table>
<thead>
<tr>
<th>Physical features of paths</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial buildings along the streets</td>
<td>20</td>
</tr>
<tr>
<td>Landscaping</td>
<td>16</td>
</tr>
<tr>
<td>Length</td>
<td>12</td>
</tr>
<tr>
<td>Width</td>
<td>10</td>
</tr>
<tr>
<td>Historical buildings along the streets</td>
<td>6</td>
</tr>
<tr>
<td>Dirty and noisy environment along the streets</td>
<td>2</td>
</tr>
<tr>
<td>Pavements (well preserved and beautiful)</td>
<td>1</td>
</tr>
</tbody>
</table>
5.3.3 Summary

The data analyses in this section indicated that there is an association between human cognitive representations (i.e., landmark buildings and paths) and spatial configuration of the urban environment.

For landmarks, global integration has the highest correlation with landmark scores; this is followed by local integration. Interviews with residents showed that distinctiveness, historical meaning, function, and location of landmark buildings are important physical features for landmark recognition. The results of a multiple regression model that included landmark score as a dependent variable, and three syntactical measures and four objective physical features of buildings as independent variables showed that global integration is the only variable explaining the variation in landmark scores ($R^2=0.26, p=0.001$).
Path scores have high bivariate correlations with all three syntactical measures. The results of the multiple regression model that included path score as a dependent variable and the three syntactical measures as independent variables indicated that local integration and connectivity are the two variables explaining the variation in path scores ($R^2=0.55$, $p=0.000$).

Overall, the results indicated that for residents' landmark recognition, the overall global syntactical accessibility is important, whereas the local syntactical accessibility is important for residents' path recognition.
5.4 THE ROLE OF INTELLIGIBILITY IN SPATIAL COGNITION

The second question focuses on exploring the role of neighborhood intelligibility in spatial cognition. This question is answered by investigating: a) the relationships between neighborhood intelligibility and cognitive representations; b) the differences in accuracy of cognitive representations between the two neighborhoods with different intelligibility values; and c) the differences in relationships between cognitive representations and three syntactical measures between the two neighborhoods with different intelligibility values.

This section consists of four parts. In the first part, the results of a multiple regression analysis performed to investigate the predictive power of the three syntactical properties as independent variables and interaction terms of intelligibility and syntactical measures on cognitive representations (i.e., landmarks and paths) will be presented. The second part will present the differences in accuracy of cognitive representations between the two neighborhoods that have different intelligibility degree. In the third part, the relationships between cognitive representations and spatial configuration between the two neighborhoods will be compared. Finally, findings of this stage will be summarized.

5.4.1 The Relationships Between Neighborhood Intelligibility and Cognitive Representations

To understand the role of neighborhood intelligibility in residents’ spatial cognition as part of the relationship study, a series of regression models were performed. These models included a landmark score or path score as a dependent variable, actual intelligibility value and syntactical measures as independent variables, and the cross product of intelligibility value and the three syntactical measures as interaction terms.
The result of the regression analysis revealed that none of the three interaction terms were significant ($p=0.994$; $p=0.556$; and $p=0.367$). Therefore, the three interaction terms were dropped from the model. On the other hand, there was also a strong collinearity between global integration and local integration (VIF$>4$), thus local integration was dropped from the model. Finally, the regression analysis showed that global integration and intelligibility were the two significant variables explaining the variation in landmark scores. They together explain 44% of the variation in landmark scores (Table 19). The model showed that higher landmark scores are associated with higher global integration and lower intelligibility of the neighborhood. It is interesting to note that when intelligibility was included into the model together with global integration, the explained variance in the landmark score increased from 26% (see Table 8) to 44% (see Table 19).

Table 19: Regression of Landmark Scores on Global Integration, Connectivity, and Intelligibility for the Two Neighborhoods.

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Integration</strong></td>
<td>0.79</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Intelligibility</strong></td>
<td>-0.45</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Connectivity</strong></td>
<td>-0.11</td>
<td>0.581</td>
</tr>
</tbody>
</table>

$R^2=0.44$, $P=0.000$, $N=42$ landmarks

Dependent variable: landmark score

The second set of regression models was performed to examine the predictive power of intelligibility on path scores. The result of the regression analysis again revealed that the three interaction terms were not significant ($p=0.560$; $p=0.451$; and $p=0.320$). In this regard, the three interaction terms were dropped from the model. In addition, because of a strong collinearity, global integration was also dropped from the model. The final regression analysis showed that local integration, connectivity, and intelligibility are the three variables
explaining the variation in path scores. They explain 61% of the variation in path scores (Table 20). The model showed that higher path scores are associated with higher local integration, higher connectivity, and lower intelligibility of the neighborhood. Similar to landmark scores, when intelligibility was added to the model together with local integration and connectivity, the explained variance in path scores increased from 55% (see Table 16) to 61% (see Table 20).

Table 20: Regression of Path Scores on Local Integration, Connectivity, and Intelligibility for the Two Neighborhoods

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Integration</td>
<td>0.53</td>
<td>0.001</td>
</tr>
<tr>
<td>Connectivity</td>
<td>0.39</td>
<td>0.018</td>
</tr>
<tr>
<td>Intelligibility</td>
<td>-0.27</td>
<td>0.041</td>
</tr>
</tbody>
</table>

\[R^2=0.61, \text{ P}=0.000, \text{ N}=36 \text{ paths}\]

Dependent variable: path score

5.4.2 Comparative Analysis of Accuracy of Cognitive Representations Between Two Neighborhoods

The differences in accuracy of cognitive representations between the two neighborhoods with different intelligibility values were addressed by a causal comparative study. In this part, the accuracy of cognitive representations was measured by resident’s landmark scores and resident’s path scores. Then, resident’s landmark scores and resident’s path scores will be compared respectively across the two neighborhoods. In this regard, the analysis will reveal the differences in accuracy of cognitive representations between the high intelligible and the low intelligible neighborhoods. Resident’s landmark score or resident’s path score was the total landmark or path scores in his/her sketch map.
First, the mean of resident’s landmark scores for each neighborhood was calculated by averaging the total resident’s landmark scores with the number of respondents in the neighborhoods. Then, a statistical test was performed to test if there are statistical significant differences between the mean resident’s landmark scores between the two neighborhoods. As Table 21 shows, the mean resident’s landmark score for the Dong-pai-lou and Roang-wan-zhen neighborhoods are 8.81 and 16.6, respectively. A Z test reveals that the difference in mean resident’s landmark scores between the two neighborhoods is not significant (p=0.095).

Table 21: Resident's Landmark Scores for the Two Neighborhoods

<table>
<thead>
<tr>
<th></th>
<th>N (Residents)</th>
<th>Resident's Landmark Score (Mean)</th>
<th>Standard Deviation</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-pai-lou</td>
<td>32</td>
<td>8.81</td>
<td>5.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intelligibility: 0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rong-wan-zhen</td>
<td>33</td>
<td>16.61</td>
<td>7.96</td>
<td>1.68</td>
<td>0.095</td>
</tr>
<tr>
<td>Intelligibility: 0.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Second, the mean of resident’s path scores for each neighborhood was calculated by averaging the total resident’s path scores with the number of residents and compared. As Table 22 shows, the mean resident’s path scores for Dong-pai-lou and Rong-wan-zhen are 35.09 and 13.97, respectively. The difference between the two means is significant (p=0.000).

Table 22: Resident's Path Scores for the Two Neighborhoods

<table>
<thead>
<tr>
<th></th>
<th>N (Residents)</th>
<th>Resident's Path Score (Mean)</th>
<th>Standard Deviation</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-pai-lou</td>
<td>32</td>
<td>35.1</td>
<td>12.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intelligibility: 0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rong-wan-zhen</td>
<td>33</td>
<td>13.97</td>
<td>6.64</td>
<td>8.61</td>
<td>0.000</td>
</tr>
<tr>
<td>Intelligibility: 0.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overall, the findings indicated that there was no statistically significant difference in the residents’ mean landmark scores between the high intelligible neighborhood (Dong-pai-lou) and the low intelligible neighborhood (Rong-wan-zhen). However, the residents’ mean path score in the high intelligible neighborhood (Dong-pai-lou) was higher than that in the low intelligible neighborhood (Rong-wan-zhen) and the difference between them is statistically significant.

5.4.3 Comparative Analysis of Relationships Between Cognitive Representations and Spatial Configuration Between Two Neighborhoods

The differences in relationships between cognitive representations and spatial configuration between the two neighborhoods with different intelligibility values were examined by a causal comparative study.

5.4.3.1 Comparison of the Relationships Between Landmark Scores and Syntactical Measures Between the Two Neighborhoods

First, a bivariate correlation analysis was conducted to explore the relationships between landmark scores and syntactical measures in each neighborhood. As shown in Figure 40, in both neighborhoods, global integration has the highest correlation with the landmark score. Also, the matrix shows that the correlation coefficients for all syntactical measures are higher for the Dong-pai-lou neighborhood (high intelligibility) than those for the Rong-wan-zhen neighborhood (low intelligibility).
Next, a bivariate regression analysis was conducted to examine the predictive power between the landmark score as a dependent variable and one of the three syntactical measures as an independent variable for each neighborhood. The results showed that for the Dong-pai-lou neighborhood, global integration is the strongest variable ($R^2=0.53$, $p=0.000$) explaining the variation in landmark scores, following by local integration and connectivity (i.e., $R^2=0.40$, $p=0.000$ and $R^2=0.28$, $p=0.010$). By contrast, for the Rong-wan-zhen, both global integration and local integration explain the same amount of the variation in landmark scores (i.e., $R^2=0.36$, $p=0.001$), whereas connectivity alone explains 22% of the variance. In addition, the coefficient of determinations for all syntactical measures are higher for the Dong-pai-lou neighborhood (high intelligibility) than those for the Rong-wan-zhen neighborhood (low intelligibility).
Third, for each neighborhood, a separate multiple regression analysis was performed to examine the predictive power between the landmark score as a dependent variable and the other three syntactical measures as independent variables. Since for both neighborhoods there was a strong collinearity between global integration and local integration, local integration was excluded from the models. Finally, the results of the regression analysis showed that global integration is the only variable explaining the variation in landmark scores in each of the two neighborhoods. However, in the Rong-wan-zhen neighborhood (low intelligibility), global integration explains 35% of the variation in landmark scores ($R^2=0.35$, $p=0.00$), whereas in the Dong-pai-lou neighborhood (high intelligibility), it explains 54% of the variation in landmark scores ($R^2=0.54$, $p=0.00$). The findings indicated that the predictive power of global integration is much higher in the more intelligible neighborhood than in the less intelligible neighborhood (Table 23).

Table 23: Regression of Landmark Scores on Global Integration and Connectivity for the Two Neighborhoods (Residents).

<table>
<thead>
<tr>
<th></th>
<th>Dong-pai-lou</th>
<th>Rong-wan-zhen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(High Intelligibility)</td>
<td>(Low Intelligibility)</td>
</tr>
<tr>
<td>Beta</td>
<td>0.93</td>
<td>0.62</td>
</tr>
<tr>
<td>P</td>
<td>0.000</td>
<td>0.030</td>
</tr>
<tr>
<td>Global Integration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connectivity</td>
<td>-0.24</td>
<td>-0.03</td>
</tr>
<tr>
<td></td>
<td>0.407</td>
<td>0.928</td>
</tr>
<tr>
<td>N=21 landmarks, $R^2=0.55$, $p=0.000$</td>
<td>N=21 landmarks, $R^2=0.35$, $p=0.000$</td>
<td></td>
</tr>
</tbody>
</table>
5.4.3.2 Comparison of the Relationships Between Path Scores and Syntactical Measures Between the Two Neighborhoods

A bivariate correlation analysis was also conducted to examine the relationships between path scores and syntactical measures in each neighborhood. As shown in Figure 41, in the Dong-pai-lou neighborhood (more intelligible), local integration and connectivity have the highest correlations with the path scores ($r=0.73$ and $r=0.71$, $p=0.000$). By contrast, in the Rong-wan-zhen neighborhood (less intelligible), local integration and global integration have the highest correlation with the path score ($r=0.80$, $p=0.002$ and $r=0.78$, $p=0.004$). While the axial lines between the two neighborhoods are the same (38 axial lines), residents in Dong-pai-lou were able to recognize more paths (24 streets) than in Rong-wan-zhen (12 streets).

<table>
<thead>
<tr>
<th></th>
<th>Global Int.</th>
<th>P</th>
<th>Local Int.</th>
<th>P</th>
<th>Con.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-pai-lou</td>
<td>$r=0.67$</td>
<td>0.000</td>
<td>$r=0.71$</td>
<td>0.000</td>
<td>$r=0.73$</td>
<td>0.000</td>
</tr>
<tr>
<td>Intelligibility: 0.58</td>
<td>R$^2=0.45$</td>
<td>0.001</td>
<td>R$^2=0.50$</td>
<td>0.002</td>
<td>R$^2=0.53$</td>
<td>0.000</td>
</tr>
<tr>
<td>(N=24 Paths)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rong-wan-zhen</td>
<td>$r=0.78$</td>
<td>0.004</td>
<td>$r=0.80$</td>
<td>0.002</td>
<td>$r=0.60$</td>
<td>0.038</td>
</tr>
<tr>
<td>Intelligibility: 0.37</td>
<td>R$^2=0.61$</td>
<td>0.027</td>
<td>R$^2=0.64$</td>
<td>0.001</td>
<td>R$^2=0.36$</td>
<td>0.029</td>
</tr>
<tr>
<td>(N=12 Paths)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 41: Comparison of the Relationships Between Path Scores and Three Syntactical Measures Between the Two Neighborhoods (Residents).
Next, three bivariate regression analyses were conducted to examine the predictive power between the path score as a dependent variable and one of the three syntactical measures as independent variables. The results showed that for the Dong-pai-lou neighborhood, connectivity is the strongest variable ($R^2=0.53$, $p=0.000$) explaining the variation in landmark scores, followed by local integration and global integration (i.e., $R^2=0.50$, $p=0.002$ and $R^2=0.45$, $p=0.001$). By contrast, for Rong-wan-zhen, local integration is the strongest variable explaining the variation in landmark scores ($R^2=0.64$, $p=0.001$), followed by global integration and connectivity ($R^2=0.61$ and $R^2=0.36$) (Figure 41).

Third, for each neighborhood multiple regression analysis was performed to examine the predictive power between path score as a dependent variable and the three syntactical measures as independent variables. In the tested models, a strong collinearity between global integration and local integration was detected, thus global integration was dropped from the models. The results of the final regression analysis showed that in the Dong-pai-lou neighborhood (high intelligibility) local integration and connectivity are the two variables explaining the variation in path scores. They together explain 62% of the variation in path scores. As for the Rong-wan-zhen neighborhood (low intelligibility), the results of the regression analysis showed that local integration is the only variable explaining the variation in path scores. It explains 65% of the variation in path scores (Table 24). The results showed that the difference in the overall coefficient of determination of the path scores between the two neighborhoods is small. However, in the less intelligible neighborhood, only local integration significantly explains path scores, whereas in the high intelligible neighborhood, both local integration and connectivity play an important role in determining path scores.
Table 24: Regression of Path Scores on Local Integration and Connectivity for the Two Neighborhoods (Residents).

<table>
<thead>
<tr>
<th></th>
<th>Dong-pai-lou (High Intelligibility)</th>
<th>Rong-wan-zhen (Low Intelligibility)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>P</td>
</tr>
<tr>
<td>Local Integration</td>
<td>0.39</td>
<td>0.05</td>
</tr>
<tr>
<td>Connectivity</td>
<td>0.47</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>N=24 paths, R²=0.62, P=0.000,</td>
<td>N=12 paths, R²=0.65, P=0.000</td>
</tr>
</tbody>
</table>

5.4.4 Summary

The results suggest that intelligibility plays an important role in cognitive representations of the residents.

First, the regression analysis showed that global integration and intelligibility of the neighborhood are both significant variables explaining the variation in landmark scores (R²=44%, p=0.000). For paths, the regression analysis showed that local integration, connectivity, and intelligibility have a strong predictive power in explaining the variation in path scores (R²=61%, p=0.000). However, for landmark recognition, the intelligibility is negatively associated with landmark scores and global integration is positively associated with landmark scores. For path recognition, the intelligibility is negatively associated with path scores and local syntactical measures (i.e., local integration and connectivity) are positively associated with path scores.

Second, the findings indicate that there are no significant differences in landmark accuracy between the two neighborhoods. But significant differences are found in path accuracy between the two neighborhoods. Overall, the results indicate that intelligibility plays an
important role in path recognition. Higher intelligibility results in greater accuracy of path recognition. It is noted that the findings are inconsistent with the results found in the multiple regression analysis discussed above. In the multiple regression model, it was found that intelligibility is negatively correlated with landmark scores and path scores, whereas based on the comparative analysis, this relationship is positive for path scores and no relationship for landmark scores. Why does this happen? The possible explanation may be attributed to the differences in the unit of analysis between the two analytical techniques. In the multiple regression analysis, when the two neighborhoods are considered together, the unit of analysis was building (landmark score) and path (path score), whereas in the comparative analysis the unit of analysis was individual (resident’s landmark and path score).

Third, the correlations between landmark scores and the three syntactical measures are stronger in a more intelligible neighborhood (Dong-pai-lou) than in a less intelligible neighborhood. Although for both of the neighborhoods, global integration is the only variable explaining the variation in landmark scores in the regression models, the explanatory power of global integration ($R^2$) is much higher in the more intelligible neighborhood (i.e., Dong-pai-lou) than in the less intelligible neighborhood, i.e., 54% vs. 35%, respectively.

Fourth, a bivariate analysis revealed that in a more intelligible neighborhood (Dong-pai-lou), connectivity and local integration have the highest correlations with path scores, i.e., 0.73 and 0.71, respectively. On the other hand, in a less intelligible neighborhood, local integration and global integration have the highest correlations with landmark scores, i.e., 0.80 and 0.78, respectively. Further, the results of multiple regression analyses showed that in a more intelligible neighborhood, local integration and connectivity are the two variables explaining the variation in path score ($R^2=0.62$, $p=0.000$), whereas in a less intelligible neighborhood local integration has become the only variable explaining the variation in landmark scores ($R^2=0.65$, $p=0.000$).
Overall, the findings implied that in a more intelligible neighborhood, the role of spatial configuration is more important than in a less intelligible neighborhood, since global integration explain more variance of landmark scores than in a less intelligible neighborhood. Also the two local syntactical measures (i.e., local integration and connectivity) are strong predictors in explaining the variance of path scores in a higher intelligible neighborhood compared to one local syntactical measure (i.e., local integration) in a less intelligible neighborhood.
5.5 THE EFFECTS OF INTELLIGIBILITY ON PERCEIVED LEGIBILITY OF THE NEIGHBORHOODS

This section will discuss the results of the experimental study conducted with the students from the Central South University in Changsha. The experimental study aims to examine how spatial configuration of the urban environment as measured by intelligibility, affects the perceived legibility of the urban environment. In this study, perceived legibility of the neighborhood is measured by sketch maps, scene recognition (recognition tests), and post-experimental interviews. In this section, the findings from sketch maps, scene recognition, and post-experimental interviews will be presented separately.

5.5.1 The Relationships Between Intelligibility and Accuracy of Cognitive Representations

Based on the coding system described in Section 4.1.5, the accuracy of cognitive representation in sketch maps is measured by student’s landmark score and student’s path score.

Similar to the procedure for analyzing the residents’ sketch maps (Section 5.4.2), student’s landmark score or student’s path score are the sum of all landmark scores or tall path scores for landmarks or paths drawn by a student respondent.

First, student’s landmark scores for landmarks that were included in the sketch maps for each neighborhood was calculated and compared. As Table 25 shows, the mean student’s landmark scores for the Dong-pai-lou and the Roang-wan-zhen neighborhoods are 11.60 and 10.70, respectively. A T test reveals that the difference in mean values between the two neighborhoods is not statistically significant (p=0.679). These results showed that there is no
difference in student’s landmark scores between the two neighborhoods.

Table 25: Student’s Landmark Scores for the Two Neighborhoods.

<table>
<thead>
<tr>
<th></th>
<th>N (Students)</th>
<th>Student’s Landmark Score (Mean)</th>
<th>Standard Deviation</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-pai-lou</td>
<td>25</td>
<td>11.60</td>
<td>7.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intelligibility: 0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rong-wan-zhen</td>
<td>23</td>
<td>10.70</td>
<td>7.12</td>
<td>0.42</td>
<td>0.680</td>
</tr>
<tr>
<td>Intelligibility: 0.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Second, student’s path scores for paths included in the sketch maps for each neighborhood were calculated and then compared. As Table 26 shows, the mean student’s path scores for Dong-pai-lou and Rong-wan-zhen are 33.12 and 13.30, respectively. The difference between the two is statistically significant (p=0.000). Overall, the findings indicated that students were able to more accurately draw the paths in the high intelligible neighborhood than in the low intelligible neighborhood.

Table 26: Student’s Path Scores for the Two Neighborhoods.

<table>
<thead>
<tr>
<th></th>
<th>N (Students)</th>
<th>Student’s Path Score (Mean)</th>
<th>Standard Deviation</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-pai-lou</td>
<td>25</td>
<td>33.12</td>
<td>11.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intelligibility: 0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rong-wan-zhen</td>
<td>23</td>
<td>13.30</td>
<td>7.81</td>
<td>6.85</td>
<td>0.000</td>
</tr>
<tr>
<td>Intelligibility: 0.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Similar to the results from residents (Section 5.4.2), the findings indicated that there is a statistical significant difference in path recognition between the two neighborhoods. Students in a high intelligible neighborhood (Dong-pai-lou) drew more accurate paths than those in a less intelligible neighborhood (Rong-wan-zhen). While the mean landmark scores for students in a high intelligible neighborhood is larger than that in a less intelligible
neighborhood, the difference in mean values between the two neighborhood is not statistically significant.

5.5.2 The Relationships Between Intelligibility and Accuracy of Scene Recognition

Besides comparing accuracy of sketch map across the two neighborhoods, recognition tests were also utilized to measure the legibility of the neighborhoods as perceived by the students. Recognition tests measured the accuracy of locations of scenes that were recognized by students. A total of 16 scenes were presented for each neighborhood and the possible range of score was from 0 to 24. The accuracy of locations of scenes were calculated based on the coding system described in Section 4.2.4. For the Dong-pai-lou neighborhood (high intelligibility), the mean score of scene recognition is 6.72. By contrast, the mean score of scene recognition for the Rong-wan-zhen neighborhood (low intelligibility) is 4.70, which is much smaller than the score for the high intelligible neighborhood. A T test revealed that the difference in the mean score of scene recognition between the two neighborhoods is significant (p=0.038). The findings indicated that intelligibility has effect on scene recognition. Overall, the results implied that students in the more intelligible neighborhood were able to correctly recognize more scenes than those in the less intelligible neighborhood. The summary of the results is shown in Table 27.

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>N (Students)</th>
<th>Mean Score</th>
<th>Standard Deviation</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-pai-lou Intelligibility: 0.58</td>
<td>25</td>
<td>6.72</td>
<td>3.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rong-wan-zhen Intelligibility, 0.37</td>
<td>23</td>
<td>4.70</td>
<td>3.27</td>
<td>2.17</td>
<td>0.038</td>
</tr>
</tbody>
</table>

Note: the range of the scores for a respondent is from 0 to 24.
Further analysis was performed to compare the percentage of correctly recognized scenes in roads with different global integration values. The scenes were purposefully selected based on their locations in the streets with different global integration values. For each of the three categories of global integration values (high, medium, and low), there were four scenes selected. For both neighborhoods, the three categories were divided based on the global integration values, which was the top 10% of high global integration axial lines, 50% of medium global integration lines, and 40% of low global integration lines.

The results indicated that there are significant differences in percentage of scenes that were correctly/partially correctly recognized along high and low integration roads between the two neighborhoods (Table 28). The students that traveled in the Dong-pai-lou neighborhood (high intelligibility) were able to correctly/partially correctly recognize more scenes in the roads with high and low global integration values than those that traveled in the Rong-wan-zhen neighborhood (low intelligibility). However, the difference in percentage of correct/partially correct scene recognition along medium global integration roads between the two neighborhoods is small and statistically insignificant.

The scenes in high global integration roads that residents recognized most were major roads with a lot of commercial/mixed use buildings on the either side of the streets. By contrast, the scenes in low global integration that students recognized least were mostly alleys or small streets in residential areas. On the other hand, three of four scenes that were photographed outside the neighborhoods were mistakenly recognized as the scenes in the neighborhoods by student respondents.
Table 28: Correctness/Part Correctness of Scene Recognition by Global Integration Categories for the Two Neighborhoods (Students).

<table>
<thead>
<tr>
<th></th>
<th>N (Students)</th>
<th>Percentage of Scene Recognition</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dong-pai-lou</td>
<td>25</td>
<td>63.0%</td>
<td>15.0%</td>
</tr>
<tr>
<td>Intelligibility: 0.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rong-wan-zhen</td>
<td>23</td>
<td>41.3%</td>
<td>17.5%</td>
</tr>
<tr>
<td>Intelligibility: 0.37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>NA</td>
<td>0.008</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Overall, the results also showed that the students in both neighborhoods are able to correctly/partially correctly recognize more scenes associated with higher global integration roads than in lower ones. With the decrease of global integration values, the percentage of correctly and partially correctly recognized scenes decreases as well (Figure 42).
5.5.3 Post-Experimental Interviews

Post-experimental interviews were utilized as a supplementary approach for measuring legibility of neighborhoods as perceived by students. The interviews included two categories: spatial cognition ability and wayfinding behavior survey. The results of the post-experimental interviews are summarized in Table 29.
Table 29: Perceived Spatial Cognition Ability and Wayfinding Behavior for the Two Neighborhoods (students).

<table>
<thead>
<tr>
<th></th>
<th>Dong-pai-lou</th>
<th>Rong-wan-zhen</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean/Percentage</td>
<td>Mean/Percentage</td>
<td></td>
</tr>
<tr>
<td>Q1: Ease of drawing the sketch maps</td>
<td>0.32 (1.89)</td>
<td>-0.87(1.98)</td>
<td>0.039</td>
</tr>
<tr>
<td>Q2: Confidence in sketch map drawing</td>
<td>1.76 (1.33)</td>
<td>0.70(1.87)</td>
<td>0.027</td>
</tr>
<tr>
<td>Q3: Confidence in recognition tests</td>
<td>0.48 (1.76)</td>
<td>-0.78 (2.07)</td>
<td>0.027</td>
</tr>
<tr>
<td>Q4: Capability of giving direction to strangers</td>
<td>44% (Yes), 48% (Fair), 8% (No)</td>
<td>43% (Yes), 39% (Fair), 18% (No)</td>
<td>0.588</td>
</tr>
<tr>
<td>Q5: Confidence in giving direction to strangers</td>
<td>0.96 (1.54)</td>
<td>0.26 (1.94)</td>
<td>0.171</td>
</tr>
</tbody>
</table>

Note: Standard deviation in parenthesis except for Q4

The range of scores except for Q4: 4 (high), 0 (Neutral), -4 (low)

As Table 29 shows, the mean scores for question 1 through question 3, which focus on examining the residents' capability and confidence in sketch map drawings and recognition tests, are much higher in the Dong-pai-lou neighborhood (high intelligibility) than in the Rong-wan-zhen neighborhood (low intelligibility). T-tests reveal that those differences are significant since their p-values are below 0.05. The findings indicate that students in the Dong-pai-lou neighborhood felt that it was easier to draw the sketch maps, they had strong
confidence in drawing the sketch maps, and they also had more confidence in recognizing
the scenes. In addition, in both neighborhoods, students perceived higher confidence in
drawing sketch maps (1.76 and 0.70) than in the ease of drawing the sketch maps (0.32 and
–0.87) and in the confidence in recognizing scenes (0.48 and –0.78).

For the other two variables (question 4 and question 5), which focus more on surveying
wayfinding performance, the differences between the neighborhoods are insignificant
(p>0.05). It is noted that for the Dong-pai-lou Neighborhood (high intelligibility), 92% of the
students (“yes” and “fair” categories) felt capable of giving direction to strangers, whereas
82% of the students for the Rong-wan-zhen neighborhood (low intelligibility) felt capable of
giving directions to strangers, about 10% less than in the high intelligible neighborhood. The
findings indicated that students in both neighborhoods felt capable of giving direction to
strangers. However, they are quite neutral in their confidence in giving directions (question
5). This is not surprising since students were novices in regard to the neighborhoods.

Overall, the analysis showed that the differences in the three major indicators related to the
perceived spatial cognition measures between the two neighborhoods are significant. These
findings indicated that students in the more intelligible neighborhood (Dong-pai-lou) felt that
they were able to more easily read the neighborhood environment and were more confident
and capable in drawing the sketch maps than those in the less intelligible neighborhood
(Rong-wan-zhen)

5.5.4 Summary

The results from the experimental study indicate that students in a more intelligible
neighborhood are able to draw more accurate paths in sketch maps and perform better in
recognizing scenes than students in the less intelligible neighborhood. However, there is no
difference in accuracy of path recognition between the two neighborhoods. Moreover, the three major indicators related to perceptions of spatial cognition ability in post-experimental interviews are also higher for students in a more intelligible neighborhood than those in a less intelligible one. Overall, the findings of the sketch maps, the recognition tests, and the three major indicators of post-experimental interviews that investigated students’ perceived spatial cognition ability partially supported the hypotheses raised in the conceptual model that the intelligibility of an area effects the perceived legibility of the urban environment (i.e., the higher the intelligibility of an area is, the more legibly the environment is reflected in the human mind).
In order to understand the differences in cognitive maps between familiar and unfamiliar people, the data obtained from residents of the two neighborhood (correlational study) and students who performed short exploratory travel through these two neighborhoods (experimental study) was utilized. The results of the data analysis will be presented in four parts. The first two parts will discuss the relationships between cognitive representations (i.e., landmarks and paths) and spatial configuration of the neighborhoods based on the data obtained from students. Similar analysis for the data obtained from residents was previously analyzed and presented in Section 5.3. In the third part, the differences in the relationships between cognitive representations and spatial configuration across residents and students will be analyzed. Finally, the summary will be drawn based on the findings.

Figure 43 shows the landmarks and paths that have been included in all 48 sketch maps drawn by the students exploring the two neighborhoods. The landmarks and paths have been scored based on the procedure discussed in Section 4.1.5. The landmark scores and path scores indicate the frequency and the degree of accuracy of elements that were drawn by students.
Figure 43: Landmarks and Paths Included in the Students’ Sketch Maps Within the Two Neighborhoods.

Note: Landmark score and path score represent the frequency and accuracy of elements drawn in the sketch maps.
5.6.1 The Relationships between Landmark Scores and Spatial Configuration for Students

In this part, first, the results of the students’ sketch map analysis will be presented. Second, an analysis combining landmark scores, building characteristics, and syntactical measures will be introduced.

The Results of Students’ Sketch Map Analysis

Students identified a total of 36 landmark buildings in their sketch maps within the two neighborhoods, compared with a total of 42 landmark buildings for residents. To analyze the students’ sketch maps, first, the landmarks that students drew in the sketch maps were coded using the same approach that was used to code landmarks drawn in the residents’ sketch maps (See Section 4.1.5). Next, each landmark building was assigned the three syntactical measures of the nearest axial line by using a spatial joint function in GIS (Figure 44 and Figure 45).
Figure 44: Landmark Buildings Included in the Students’ Sketch Maps Within the Two Neighborhoods.

Note: Landmark score represents the frequency and locational accuracy of elements drawn in the sketch maps.
Figure 45: Overlay of Landmark Scores and Global Integration of the Two Neighborhoods (Students).

Note: Landmark score represents the frequency and locational accuracy of elements drawn in the sketch maps.
To examine the relationships between landmark scores and the three syntactical measures (i.e., global integration, local integration, and connectivity), a bivariate correlation analysis, a bivariate regression analysis, and a multiple regression analysis were performed.

First, a bivariate correlation analysis was utilized to understand the relationships between landmark scores and the three syntactical measures of spatial configuration. As shown in Figure 46, global integration has the strongest and significant correlation with landmark scores ($r=0.57$, $p=0.000$), followed by connectivity ($r=0.46$, $p=0.002$) and local integration ($r=0.47$, $p=0.002$).

Next, a bivariate regression analysis was conducted to examine the predictive power between the landmark score as a dependent variable and one of the three syntactical measures as an independent variable. The results showed that global integration is the strongest variable ($R^2=0.32$, $p=0.000$) explaining the variation in landmark scores, followed
by connectivity ($R^2=0.22$, $P=0.001$) and local integration ($R^2=0.21$, $P=0.001$) (Figure 46).

Finally, a multiple regression analysis was performed to examine the predictive power between the landmark score as a dependent variable and the three syntactical measures as independent variables. When all three independent variables were included, a strong collinearity between global integration and local integration was detected ($VIF>4$). Thus, local integration was dropped from the model. Overall, the results of the regression analysis showed that global integration is the only significant variable explaining the variation in landmark scores (Table 30). For the two neighborhoods together, global integration explains 32% of the variation in landmark scores ($R^2=0.32$, $p=0.000$).

Table 30: Regression of Landmark Scores on Global Integration and Connectivity for the Two Neighborhoods (Students).

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Integration</td>
<td>0.51</td>
<td>0.027</td>
</tr>
<tr>
<td>Connectivity</td>
<td>0.07</td>
<td>0.761</td>
</tr>
</tbody>
</table>

$R^2=0.32$, $P=0.000$, $N=36$ landmarks

Dependent variable: landmark score
The Relationships Between Landmark Scores, Building Characteristics, and Syntactical Measures for Students

Similar to the approach used with the data from the residents to understand the role of building characteristics in students’ landmark identification, building characteristics were included in the regression models on landmark scores. Buildings identified in the sketch maps were scored based on the same four dimensions that were used for residents: distinctiveness, historical meaning, function, and maintenance.

First, Pearson correlation coefficients for all variables in the model were calculated to understand the relationships between landmark scores and distinctiveness, historical meaning, function, and maintenance scores. As shown in Table 31, function and distinctiveness scores have strong correlations with landmark scores (i.e., $r=0.50$, $p=0.001$ and $r=0.48$, $P=0.000$) and maintenance score has a medium correlation with landmark score (i.e., $r=0.38$, $p=0.037$). Similar to the results of residents, the historical meaning score has very weak and insignificant correlation with landmark scores.

Table 31: Correlation matrix for Landmark Scores and Four Building Characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Landmark Score</th>
<th>Distinctiveness</th>
<th>Historical Meaning</th>
<th>Function</th>
<th>Maint.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark Score</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distinctiveness</td>
<td>0.48**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical Meaning</td>
<td>-0.11</td>
<td>0.11</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>0.50**</td>
<td>0.37´</td>
<td>-0.28´</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.38´</td>
<td>0.39´</td>
<td>0.13</td>
<td>0.34´</td>
<td>1</td>
</tr>
</tbody>
</table>

*$P<0.05$; **$P<0.01$  
N=36 landmarks
Then, a multiple regression analysis was performed to investigate the predictive power of four dimensions of building characteristics on landmark scores. In the regression model, the landmark score was the dependent variable, and the scores for the four building characteristics were independent variables.

As shown in Table 32, the results of the regression analysis indicated that distinctiveness and function scores are the two significant independent variables explaining the variation in landmark scores. Overall, together they explain 35% of the variation in landmark scores ($R^2=0.35$, p=0.000).

Table 32: Regression of Landmark Scores on Four Buildings Characteristics (Distinctiveness, Historical Meaning, Function and Maintenance) for the Two Neighborhoods (Students).

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distinctiveness</td>
<td>0.34</td>
<td>0.030</td>
</tr>
<tr>
<td>Function</td>
<td>0.37</td>
<td>0.020</td>
</tr>
<tr>
<td>Historical Meaning</td>
<td>-0.08</td>
<td>0.621</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.16</td>
<td>0.323</td>
</tr>
</tbody>
</table>

$R^2=0.35$, p=0.000, N=36 landmarks  
Dependent variable: landmark score

To obtain a more comprehensive understanding of students’ landmark recognition, a second multiple regression analysis was conducted to examine the relationships between the landmark scores as a dependent variable and the four building characteristic scores (i.e., distinctiveness, historical meaning, function, and maintenance of the building), and the three syntactical measures as independent variables.

Pearson correlation coefficients for all variables in the second model were calculated to
explore the relationships between syntactical measures (i.e., global integration, local integration, and connectivity) and the scores for four dimensions of building characteristics. As shown in Table 33, global integration and function scores have strong correlations with the landmark scores (i.e., $r=0.57, p<0.000$ and $r=0.50, p<0.001$). Distinctiveness, connectivity, and local integration scores have medium correlations with landmark scores ($r=0.48, p=0.001$; $r=0.47, p=0.002$; and $r=0.46, p<0.000$), followed by maintenance score ($r=0.38, p=0.003$).

Table 33: Correlation Matrix for Landmark Score, Syntactical Measures, and Building Characteristics (Students).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark Score</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Integration</td>
<td>0.57***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Integration</td>
<td>0.46**</td>
<td>0.92***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connectivity</td>
<td>0.47**</td>
<td>0.78***</td>
<td>0.72***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distinctiveness</td>
<td>0.48**</td>
<td>0.46***</td>
<td>0.24*</td>
<td>0.44*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical Meaning</td>
<td>-0.11</td>
<td>0.01</td>
<td>0.03</td>
<td>-0.05</td>
<td>0.11</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>0.50***</td>
<td>0.58***</td>
<td>0.47*</td>
<td>0.64***</td>
<td>0.37*</td>
<td>-0.28*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.38*</td>
<td>0.51***</td>
<td>0.44*</td>
<td>0.44*</td>
<td>0.39*</td>
<td>0.13</td>
<td>0.34*</td>
<td>1</td>
</tr>
</tbody>
</table>

*P<0.05; **P<0.01; ***P<0.001

N=36 landmarks

From the matrix, it is noted that there are relatively strong associations between the three syntactical measures and the function of the buildings (i.e., $r=0.58$ for global integration, $r=0.47$ for local integration, and $r=0.64$ for connectivity). This means that the buildings with
mixed and commercial uses tend to cluster along the roads with high syntactical accessibility, with respect to the whole layout or immediate streets.

In the tested multiple regression model, a strong collinearity between global integration and connectivity (VIF>4) was detected. Therefore, local integration was dropped from the model. Overall, the results of the regression analysis showed that global integration is the only significant variable explaining the variation in landmark scores (Table 34). For the two neighborhoods together, it explains 32% of the variation in landmark scores ($R^2=0.32$, $p=0.000$). These results were similar to the results obtained from the residents. However, global integration explains a larger percentage of variation on landmark scores for students than it does for the resident samples, 32% vs. 26%, respectively.

Overall, the results indicated that global integration is the only independent variable to account for the variation of landmark scores, even when the other two syntactical measures and the four building characteristic scores were considered.
Table 34: Regression of Landmark Scores on Four Buildings Characteristic Scores (Distinctiveness, Historical Meaning, Function, and Maintenance) and Two Syntactical measures (Global Integration and Connectivity) for the Two Neighborhoods (Students).

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Integration</td>
<td>0.37</td>
<td>0.027</td>
</tr>
<tr>
<td>Connectivity</td>
<td>-0.10</td>
<td>0.676</td>
</tr>
<tr>
<td>Distinctiveness</td>
<td>0.26</td>
<td>0.118</td>
</tr>
<tr>
<td>Maintenance</td>
<td>-0.10</td>
<td>0.531</td>
</tr>
<tr>
<td>Function</td>
<td>0.20</td>
<td>0.344</td>
</tr>
<tr>
<td>Historical Meaning</td>
<td>0.08</td>
<td>0.662</td>
</tr>
</tbody>
</table>

R²=0.32, P=0.000, N=36 landmarks
Dependent variable: landmark score
5.6.2 The Relationships between Path Scores and Spatial Configuration for Students

A total of 37 paths (roads/streets) were included in the students’ sketch maps within the two neighborhoods. Following the approach used with residents, each street drawn in the sketch maps was scored for frequency and accuracy based on the same coding system that was used for residents (Section 4.1.5) (Figure 47). After that, the axial lines that comprise each path within the neighborhood boundary were selected using a buffer procedure in GIS. Next, the mean value of syntactical measures (i.e., global integration, local integration, and connectivity) of axial lines covering each path was calculated and assigned to each path (Figure 48).
Figure 47: Paths Included in the Students' Sketch Maps Within the Two Neighborhoods. 
Note: Path score represents the frequency and accuracy of elements drawn in the sketch maps.
Figure 48: Overlay of paths and Global Integration of the Two Neighborhoods (Students).

Note: Path score represents the frequency and accuracy of element drawn in the sketch maps.
To explore the relationships between path scores and the three syntactical measures (i.e. global integration, local integration, and connectivity), a bivariate correlation analysis, a bivariate regression analysis, and a multiple regression analysis were performed.

Bivariate correlation analysis was utilized to understand the relationships between path scores and three syntactical measures of the spatial configuration. As shown in Figure 49, all syntactical measures have strong correlations with path scores ($r=0.70$ for global integration, $0.74$ for local integration, and $0.75$ for connectivity).

<table>
<thead>
<tr>
<th>Global Integration</th>
<th>Local Integration</th>
<th>Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r=0.70$</td>
<td>$r=0.74$</td>
<td>$r=0.75$</td>
</tr>
<tr>
<td>$R^2=0.49$</td>
<td>$R^2=0.55$</td>
<td>$R^2=0.56$</td>
</tr>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

N=37 paths

Figure 49: Correlation Coefficients and Scatterplots of the Relationships Between Path Scores and Three Syntactical Measures for Students of the Two Neighborhoods.

Next, a bivariate regression analysis was conducted to examine the predictive power between the path score as a dependent variable and one of the three syntactical measures as independent variables. The results showed that local integration and connectivity individually were able to account 56% and 55% of variance in landmark scores, while global integration accounted for 49%. Overall, the results showed that the three syntactical
measures are very close in explaining the variation in landmark scores.

Finally, a multiple regression analysis was performed to examine the predictive power between the path score as a dependent variable and the three syntactical measures as independent variables. When all three independent variables were included in the tested models, a strong collinearity between global integration and local integration was detected (VIF>4). Thus, global integration was dropped from the model. Overall, the results of the regression analysis showed that local integration and connectivity are the two significant variables explaining the variation in path scores (Table 35). For the two neighborhoods together, they explain 66% of the variation in landmark scores ($R^2=0.66$, $p=0.000$).

Table 35: Regression of Path Scores on Local Integration and Connectivity for the Two Neighborhoods (Students).

<table>
<thead>
<tr>
<th></th>
<th>Standardized Regression Coefficients (Beta)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Integration</td>
<td>0.42</td>
<td>0.037</td>
</tr>
<tr>
<td>Connectivity</td>
<td>0.46</td>
<td>0.020</td>
</tr>
</tbody>
</table>

$R^2=0.66$, $P=0.000$, $N=37$ paths
Dependent variable: path score

Similar with the approach that was used for residents, the paths that were included in the students' sketch maps were recoded to account only for spatial accuracy while street naming was excluded from the overall scores (see Section 4.1.5). Analysis showed that the results were almost the same as the findings discussed above. The bivariate correlations between path scores and the three syntactical measures are 0.70 ($p=0.001$) for global integration, 0.74 ($p=0.000$) for local integration, and 0.79 ($p=0.000$) for connectivity respectively. The multiple regression analysis also showed that local integration and connectivity are the two significant independent variables explaining the variation in path scores ($R^2=0.70$, $p=0.000$).
The findings indicated that when street naming was excluded from path scores, the explained variance increased from 66% to 70%.

5.6.3 Differences in Cognitive Representations Between Residents and Students

The differences in cognitive representations between residents and students were examined by comparing the following: a) correlation coefficients for landmarks and paths and b) coefficient of determinations and Beta values for landmarks and paths calculated for resident and student samples. In this section, absolute values of correlation coefficients, coefficient of determinations, and Beta values were compared between the two groups, since the variances across the samples are different. It is inappropriate to strictly conduct a statistical significance test for them (see Section 4.1.5).

The results obtained from resident samples (Section 5.3) and the results obtained from student samples (Section 5.6.1 and Section 5.6.2) that were previously introduced are summarized in Table 38.
By examining Table 36, it is evident that there are both differences and similarities in the cognitive maps between residents and students. First, the correlation coefficients between cognitive representations (i.e., landmarks and paths, and three syntactical measures) are stronger for students than those for residents. Second, it is evident that for both samples (residents and students) the associations between landmark scores and the three syntactical measures are lower than that between path score and the three syntactical measures. Third, the predictive power of syntactical measures \( R^2 \) on cognitive
representations for both landmarks and paths are higher for students than for residents. Fourth, for regression models for residents and students, global integration is the only variable explaining the variation in the landmark score. Similarly, local integration and connectivity are the two variables explaining the variation of path scores for both resident and student samples.

5.6.4 Summary

The findings obtained by analyzing students’ sketch maps (unfamiliar group) (Section 5.6.1 and Section 5.6.2) revealed that there is an association between cognitive representations (i.e., landmark buildings and paths) and spatial configuration of the urban environment.

Landmark scores have the highest correlation with global integration (r=0.57). This is followed by connectivity (r=0.47) and local integration (r=0.46). The results of the first multiple regression analysis that included landmark score as a dependent variable and the four building characteristic scores (i.e., distinctiveness, historical meaning, function, and maintenance) as dependent variables indicated that the distinctiveness and function of buildings are the only two significant variables in the model. For students (i.e., unfamiliar group), distinctiveness and function of the buildings played a role in identifying buildings in the neighborhoods. Both of them are able to explain 35% of the variation in landmark scores. However, for residents as the familiar group (see Section 5.3.1), distinctiveness and maintenance played a role in identifying buildings in the neighborhood, while function did not.

The results of the second multiple regression model that was utilized to analyze the predictive power between the landmark score as a dependent variable, and the three syntactical measures and the four building characteristic scores as independent variables.
showed that global integration is the only variable explaining the variation in landmark scores ($R^2=0.32$, $p=0.00$). Similar results were also found for residents ($R^2=0.26$, $p=0.001$) (see Section 5.3.1).

Path scores have the strongest correlations with local integration and connectivity ($r=0.75$ and $r=0.74$). This is followed by global integration ($r=0.70$). The results of a multiple regression model that included path scores as a dependent variable and the three syntactical measures as independent variables indicated that local integration and connectivity are the two variables explaining the variation in path scores ($R^2=0.66$, $p=0.000$).

As for students as the unfamiliar group, the comparison of the results from the first (including street name) and second (excluding street name) coding system for paths (see Section 4.5.1) indicated that the predictive power of local syntactical measures (local integration and local connectivity) on path scores has changed from 66% to 70%. This implied that for students, when the situation of street name labeling was not considered (for the second coding system), the predictive power of local syntactical measures increased. By contrast, for residents as the familiar group, when the situation of street name labeling was not considered, the predictive power of local integration and local connectivity decreased from 55% to 50% (see Section 5.3.2). These results may not be surprising, since students were newcomers, they might have had difficulty remembering names of the streets, therefore, they probably made some errors when writing the street names in their sketch maps. Therefore, when the labeling of street name was not considered in path scoring, the predictive power of syntactical measures increased. As for residents, they are familiar with the environment and capable of correctly remembering more street names than students. Therefore, when the labeling of street name was not considered in path scoring, the predictive power of syntactical measures decreased.
The comparative analysis between the results obtained from resident and student samples showed that the descriptive statistics indicating the associations (r and $R^2$) between cognitive representations and spatial configuration of the urban environment is seemingly stronger for the unfamiliar group (i.e., students) than for the familiar group (i.e., residents) (see Table 36). For both groups, the same variables accounted for variance in landmark scores (global integration) and path scores (local integration and connectivity).
CHAPTER 6: CONCLUSIONS AND DISCUSSIONS

The study had two major goals: a) to understand the relationships between cognitive representations (i.e., landmarks and paths) and spatial configuration of the urban environment and b) to examine if spatial configuration of the urban environment measured by Space Syntax as “intelligibility” affects the perceived legibility of the urban environment. This chapter will present the conclusions drawn from the findings of this study. Study limitations will also be discussed.

6.1 SUMMARY OF THE FINDINGS

6.1.1 The Relationships between Cognitive Representations and Spatial Configuration

The first section of the study aimed at examining the relationships between cognitive representations (i.e., landmarks and paths) and spatial configuration of the neighborhoods. Cognitive representations were measured mainly by sketch maps and spatial configuration was measured by Space Syntax. Three syntactical measures (global integration, local integration, and connectivity) objectively described the spatial configuration of neighborhoods. Landmark and path scores that were developed for buildings and paths included in the sketch maps measured the frequency and locational accuracy of elements (landmarks and paths) drawn by residents.

The major findings concerning the relationships between cognitive representations and spatial configuration are summarized in Table 37.
Table 37: Summary of the Relationships Between Cognitive Representations and Syntactical Measures.

<table>
<thead>
<tr>
<th>Cognitive Representations</th>
<th>Syntactical Measures</th>
<th>Global Integration</th>
<th>Local Integration</th>
<th>Connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residents (familiar people)</td>
<td>Landmark Score</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
</tr>
<tr>
<td>Residents (familiar people)</td>
<td>Path Scores</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
</tr>
<tr>
<td>Students (unfamiliar people)</td>
<td>Landmark Score</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
</tr>
<tr>
<td>Students (unfamiliar people)</td>
<td>Path Scores</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
<td>![Up Arrow]</td>
</tr>
</tbody>
</table>

Note: ↑: positive correlation  
↑: positive correlation and predictor

Bivariate analysis performed on data collected from residents (relationship study) revealed that the correlations between path scores and the three syntactical measures for residents (i.e., global integration, local integrations, and connectivity) are relatively strong (i.e., 0.68, 0.67, and 0.70 respectively). Connectivity has the highest correlation with path scores and the next high correlations are global integration and local integration. Previous literature indicated that a strong association exists between path frequency drawn in sketch maps and spatial configuration of the urban environment (Kim, 2001). In this regard, the findings of this study are similar to the results of Kim’s study conducted in the UK. However, in Kim’s study,
local integration shows the best correlation with path frequency \((r=0.708, p<0.001)\) and the next is global integration \((r=0.456, p<0.001)\). It is interesting to note that much stronger correlations between path scores and the three syntactical measures are found for the students (experimental study).

On the other hand, the results of a multiple regression analysis for both residents and students indicated that local syntactical measures (i.e., local integration and connectivity) are the two significant variables explaining the variation in path scores. Overall, for residents, these two variables account for about 55% of the variation in path scores, while global integration was highly correlated with local integration. Similar findings were also found for the students. These findings may suggest that people tend to shape road/street maps in their cognitive maps based on local syntactical accessibility (i.e., syntactical accessibility within the immediate environment).

Empirical tests of the study indicated that correlations exist between landmark scores and the three syntactical measures as well. The correlations between landmark scores and global integration and local integration for residents are 0.51 and 0.39, respectively, while no significant relationships were found between landmark scores and connectivity. Similar results are also found for the students; however the correlations for all three syntactical measures are significant and they are slightly stronger than for residents.

Previous literature indicated that characteristics of buildings, such as distinctiveness, function, historical meaning, maintenance, etc., are also important to an individual’s landmark recognition. In this study, interviews administrated with residents also showed that distinctiveness, function, historical meaning, and maintenance of buildings are features that help their landmark identification. Thus, to fully understand the predictive power of spatial configuration and building characteristics on landmark scores, a series of multiple
regression analyses that included three syntactical measures and four building characteristic scores were performed.

The results of the multiple regression analysis for both residents and students indicated that global integration is the only variable explaining the variation in landmark scores. It explains 26% of variation in landmark scores for residents and 32% for students. For both residents and students, although when considered by themselves, some of the building characteristics (such as distinctiveness, function, and maintenance) played a role in predicting landmark scores, all these variables lost their significance when global integration was included in the model. These findings showed that global accessibility is important for landmark recognition, whereas local syntactical accessibility does not play a role in recognizing landmark buildings. This suggests that individuals’ landmark knowledge is dependent on the overall distribution of movement in the urban environment.

Overall, the findings imply that people tend to recognize buildings based on the global syntactical accessibility in the neighborhood, whereas path recognition is more dependent on the accessibility within the immediate environment in the neighborhood. Both findings support the theoretical argument that the spatial configuration (global and local accessibility) is a primary root for people to shape their cognitive maps (O’Neill, 1991b; Golledge and Stimson, 1997; Jiang, 1998). The results also confirm that the connection between spatial configuration and mental structure is based on hierarchy. Hierarchies of street layout, arrangement of paths, and location of landmarks are significant in shaping an individual’s cognitive representations of the urban environment since it is the way in which our minds work (Lynch, 1981; Appleyard, 1976).
6.1.2 The Role of Intelligibility in Spatial Configuration

The second stage of the study focused on exploring the role of neighborhood intelligibility in spatial cognition. Spatial cognition was mainly measured by sketch maps and intelligibility was measured by Space Syntax methodology. This was done first by using multiple regression models to investigate the relationships between cognitive representations (landmarks and paths) and intelligibility, three syntactical measures, and interaction terms between cognitive representations and three syntactical measures for both neighborhoods together. Second, the differences in accuracy of cognitive representations (landmarks and paths), and the differences in relationships between cognitive representations (landmarks and paths) and three syntactical measures between the two neighborhoods with different levels of intelligibility were explored.

The overall findings about the role of intelligibility in spatial cognition are shown in Table 38.
Table 38: The Role of Intelligibility in Spatial Cognition.

<table>
<thead>
<tr>
<th>Accuracy of Cognitive Rep.</th>
<th>Neighborhood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Intelligibility (HI)</td>
</tr>
<tr>
<td></td>
<td>(Dong-pai-lou)</td>
</tr>
<tr>
<td>Resident’s Landmark Score</td>
<td>H_I_{mean} &lt; L_I_{mean} not significant</td>
</tr>
<tr>
<td>Resident’s Path Score</td>
<td>H_I_{mean} &gt; L_I_{mean} ***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Correlations (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark Score</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Path Score</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multiple Regressions (R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark Score</td>
</tr>
<tr>
<td>Path Score</td>
</tr>
</tbody>
</table>

Note: ***P=0.001
First, the multiple regression analysis for the two neighborhoods together indicated that intelligibility and global integration are two significant variables explaining the variation in landmark scores. They together explain 44% variance in landmark scores. In the model, global integration was positively correlated with landmark scores and intelligibility was negatively correlated with landmark scores. Local syntactical measures (local integration and connectivity) did not play a role in predicting landmark scores in the model.

As for path scores, the results of the multiple regression models for the two neighborhoods together indicated that intelligibility and local syntactical measures (local integration and connectivity) are the significant variables explaining the variance in path scores. They together explain 61% of variance in path scores. In the model, local syntactical measures were positively correlated with path scores and intelligibility was negatively correlated with path scores. Global integration did not play a role in predicting path scores in the model.

Second, to further investigating the role of intelligibility in spatial cognition, the accuracy of cognitive representations (landmarks and paths) was calculated and compared across the two neighborhoods with different levels of intelligibility.

The results showed that the mean value of resident’s path scores in a more intelligible neighborhood was much larger than those in a less intelligible one, while the differences in the mean values of resident’s landmark scores were not significant. These results may not be surprising since intelligibility defines the structural characteristics of street segments. High intelligibility means an individual easily acquires the overall street structure based on what he/she can see and experience locally in the system. Overall, the study findings revealed that individuals living in a more intelligible neighborhood are able to draw more accurate paths than people living in a less intelligible one. These findings clearly identify the
importance of intelligibility in acquiring path knowledge but not landmark knowledge. The result was also confirmed in the experimental study for an unfamiliar group (i.e., students), as discussed in Section 6.1.3.

It should be noted that the findings in the comparative analysis of accuracy of cognitive representations are not consistent with the results found in the multiple regression analysis discussed above. In the multiple regression model, it was found that intelligibility is negatively correlated with both landmark scores and path scores, whereas based on the comparative analysis this relationship is positive for path scores and no relationship for landmark scores. Why does this happen? The possible explanation may be attributed to the differences in the unit of analysis between the two analytical techniques. In the multiple regression analysis, when the two neighborhoods are considered together, the unit of analysis was an urban element (building or path), whereas in the comparative analysis the unit of analysis was an individual (resident’s landmark or path score).

Finally, the relationships between cognitive representations (landmarks and paths) for each neighborhood were calculated and compared across the two neighborhoods with different levels of intelligibility.

The results revealed that the correlations between landmark scores and the three syntactical measures are slightly higher in a more intelligible neighborhood than in a less intelligible one (0.73 vs. 0.60 for global integration, 0.63 vs. 0.60 for local integration, and 0.53 vs. 0.47 for connectivity). The results are not surprising since space syntax research has already suggested that the association between space syntax measures and observed movement weakens in unintelligible environments (Hillier, 1996). If cognitive maps are developed through movement and the spaces with high global and local accessibility attract more movement than those with low global and local accessibility, then buildings in spaces with
high global and local accessibility will leave strong impression in individuals’ minds when compared to the buildings in less accessible spaces. Therefore, when the association between movement and syntactical measures weakens (i.e., less intelligible environment) the association between cognitive representation (i.e., landmarks) and syntactical measures will also weaken.

In addition, the multiple regression analysis that included all three syntactical measures as independent variables revealed that in each neighborhood global integration is the only significant variable explaining the variance in landmark scores, whereas local syntactical measures (local integration and connectivity) do not play role in predicting landmark scores. However, the predictive power of global integration on landmark scores for the more intelligible neighborhood is larger than for the less intelligible neighborhood, 55% vs. 35%. In regard to landmark recognition, the results suggest that global accessibility within a layout is more important for people living in a more intelligible neighborhood than those in a less intelligible one.

On the other hand, the results of comparative analysis of the relationships between path scores and three syntactical measures revealed that in a high intelligible neighborhood, the correlation between path scores and connectivity is higher than that in a low intelligible neighborhood (0.73 vs. 0.60). However, the correlations between path scores and global integration and local integration in a high intelligible neighborhood are smaller than those in a low intelligible neighborhood (0.67 vs. 0.78 for global integration; 0.71 vs. 0.80 for local integration).

In addition, the results of multiple regression analysis showed that in each neighborhood, local syntactical measures (local integration and connectivity) are the two variables explaining the variance in path scores and global integration does not play a role in
predicting path scores. The differences in the predictive power of local syntactical measures on path scores between the two neighborhoods are very small (0.62 for a high intelligible neighborhood vs. 0.65 for a low intelligible neighborhood).
6.1.3 The Effects of Intelligibility on Legibility of the Urban Environment

The third question in this study focused on exploring the effects of spatial configuration, measured by intelligibility, on perceived legibility of the neighborhood. Following the definition of legibility, "the ease with which part of an urban environment can be recognized and can be organized into a coherent pattern" (Lynch, 1960, p. 9), perceived legibility of the environment was measured by students’ sketch maps, recognition tests, and post-experimental interviews. The data was obtained from the experimental study in which the group of students who were unfamiliar with the neighborhoods performed exploratory travel throughout a more intelligible or a less intelligible neighborhood. The major findings are summarized as Table 39.
Table 39: The Effects of Spatial Configuration on Legibility.

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>High Intelligibility (HI) (Dong-pai-lou)</th>
<th>Low Intelligibility (LI) (Rong-wan-zhen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student's Landmark Score</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Student's Path Score</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;***</td>
<td></td>
</tr>
<tr>
<td>Score of Scene Recognition</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;*</td>
<td></td>
</tr>
<tr>
<td>Score for Easiness of Sketch</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;*</td>
<td></td>
</tr>
<tr>
<td>Map Drawing</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;*</td>
<td></td>
</tr>
<tr>
<td>Score for Confidence in Sketch Maps</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;*</td>
<td></td>
</tr>
<tr>
<td>Score for Confidence in Scene Recognition</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;*</td>
<td></td>
</tr>
<tr>
<td>Percentage of Capability of Giving Direction (Yes &amp; Fair)</td>
<td>HI&lt;sub&gt;per&lt;/sub&gt; &gt; LI&lt;sub&gt;per&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Confidence in Giving Direction</td>
<td>HI&lt;sub&gt;mean&lt;/sub&gt; &gt; LI&lt;sub&gt;mean&lt;/sub&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Note: *P=0.05; ***P=0.001
Similar to the results from residents, the results of sketch map analysis indicated that there is a significant difference in student’s path scores between the two neighborhoods, whereas the difference in student’s landmark scores is insignificant. The findings implied that intelligibility plays a role in students’ accuracy of path recognition, but not the accuracy of landmark identification. The results of recognition tests showed that students who traveled through the more intelligible neighborhood were able to correctly recognize more scenes than those in a low intelligible one. In addition, for both neighborhoods together, it is noted that students were capable of correctly recognizing more scenes taken in higher global integration roads than in lower one. With the decrease of global integration values, the percentage of correctness of scene recognition decreases as well.

The results of post-experimental interviews showed that three major indicators that focus on exploring students’ feelings of spatial cognition ability in a high intelligible neighborhood are higher than those in a less intelligible one. The three major indicators are: easiness of sketch map drawing, degree of confidence in sketch map drawing, and degree of confidence in scene recognition.

Overall, the findings of the sketch maps, recognition tests, and major indicators of post-experimental interviews with students showed that students’ mean path scores in the sketch maps, the mean scores of scene recognition, and the three major mean scores of spatial cognition ability in a more intelligible neighborhood are much higher than in a less intelligible one. However, no difference in landmark recognition was found between the high and low intelligible neighborhoods. The findings partially confirmed the theoretical argument/hypothesis suggested by Hillier (1988, 1996) --- the more intelligible an area is, the more legibly it is reflected in the human mind. This also supported Haq’s empirical study conducted in a hospital setting (2001). In addition, the street network in the Dong-pai-lou
neighborhood exhibits a more regular and grid pattern than the network pattern in Rong-wan-zhen neighborhood. In this regard, the results of this study also supported the early study (Jone, 1962) that the residents of cities with more regular and grid street pattern draw more complete and accurate city maps. Why this is so? The reason might be that a regular and grid street pattern tends to have a higher intelligible value than an irregular street network because of large number of connections among streets.

Overall, the findings indicated that strangers or “first time” visitors tend to shape more accurate spatial cognition, particularly for path recognition and scene recognition, in a more intelligible environment than in a less intelligible one. In turn, the accurate spatial cognition in strangers may facilitate their wayfinding performance later, which has been confirmed by Peponis et al. (1990) in their wayfinding investigation within a building scale.

Why does a neighborhood with higher intelligibility structure results in higher perceived legibility? The intelligibility value describes the characteristics of the spatial configuration: the association between global and local syntactical accessibility; and the spatial configuration of the environment is the prime root by which people recognize a built environment. Thus, high intelligibility means people are able to easily and accurately read the overall structure of the urban environment based on immediate structures of the urban environment they experience. In this regard, intelligibility has positive effects on spatial cognition.
6.1.4 Spatial Cognition Patterns for Familiar and Unfamiliar Groups

In this study, the differences in spatial cognition between familiar and unfamiliar groups were analyzed by comparing the correlation and regression coefficients between cognitive representations (i.e., landmarks and paths) and the three syntactical measures (global integration, local integration, and connectivity) obtained from the studies conducted with two samples, i.e., residents (correlational) and students (experimental). The overall summary of the findings is shown in Table 40.
Table 40: Correlations Coefficients and Coefficient of Determination for Students and Residents.

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<th>Groups</th>
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<td></td>
<td>Unfamiliar Group (UFG)</td>
<td>Familiar Group (FG)</td>
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<tr>
<td></td>
<td>(Students)</td>
<td>(Residents)</td>
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<tr>
<td>Correlations</td>
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<td>(r)</td>
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<tr>
<td>Landmark Score</td>
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<tr>
<td>Global Integration</td>
<td>UFG_r &gt; FG_r</td>
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<tr>
<td>Local Integration</td>
<td>UFG_r &gt; FG_r</td>
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<tr>
<td>Connectivity</td>
<td>UFG_r &gt; FG_r</td>
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<tr>
<td>Path Score</td>
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<tr>
<td>Global Integration</td>
<td>UFG_r &gt; FG_r</td>
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<tr>
<td>Local Integration</td>
<td>UFG_r &gt; FG_r</td>
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<tr>
<td>Connectivity</td>
<td>UFG_r &gt; FG_r</td>
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<td>(R²)</td>
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<tr>
<td>Landmark Score/Global Integration</td>
<td>UFG_R² &gt; FG_R²</td>
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<td>Path Score/Local Integration + Connectivity</td>
<td>UFG_R² &gt; FG_R²</td>
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The comparison of bivariate correlation analysis indicated that for students as an unfamiliar group, the correlations between landmark scores and the three syntactical measures are slightly larger than those for residents as a familiar group: 0.57 vs. 0.51 for global integration, 0.47 vs. 0.40 for local integration, and 0.46 vs. 0.23 for connectivity. Similar results are also found in correlations between path scores and the three syntactical measures between students and residents: 0.70 vs. 0.68 for global integration, 0.74 vs. 0.67 for local integration, and 0.75 vs. 0.70 for connectivity.
In addition, the magnitude of predication of local syntactical measures on path scores is higher for students (unfamiliar group) than for residents (familiar group), 66% vs. 55%. While statistically it is not meaningful to compare the differences in standardized scores (such as r and $R^2$) across the two models (familiar and unfamiliar groups) (Davidson and Mackinnon, 2004), these findings suggested that syntactical accessibility within the immediate environment is more important for newcomers’ path recognition than for familiar people. On the other hand, the power of prediction of global integration on landmark scores is also higher for students (unfamiliar group) than for residents (familiar group), 32% vs. 26%. The findings indicated that for landmark recognition, overall accessibility within a layout is more important for newcomers to an unfamiliar area than for people familiar with the area.

When comparing the results from the first (including street names) and second coding (excluding street names) systems for paths (see Section 4.5.1) for students as an unfamiliar group, it was found that the predictive power of local syntactical measures (local integration and local connectivity) on path scores has changed from 66% to 70%. This implied that for students, when the situation of street name labeling was not considered (for the second coding system), the predictive power of local syntactical measures increased. By contrast, for residents as an unfamiliar group, when the situation of street name labeling was not considered, the predictive power of local syntactical measures decreased from 55% to 50% (see Section 5.3.2). These results may not be surprising, since students were newcomers, they will have more difficulty remembering names of streets than residents. Therefore, they probably made errors in writing street names in their sketch maps. Therefore, when the labeling of street name was not considered in path scoring, the predictive power of local syntactical measures increased. By contrast, residents are familiar with the environment and are capable of correctly remembering more street names than students. In this regard, when the labeling of street name was not considered in scoring, the predictive power of local...
syntactical measures decreased, which indicate that for residents living in the area, other factors than local syntactical properties also start to play role in building path knowledge.

In general, the study findings have shown that the associations between cognitive representations and the three syntactical measures and the predicative power of local syntactical measures (i.e., local integration and local connectivity) are seemingly stronger for the unfamiliar group than those for the familiar group. These results indicated that individuals unfamiliar with the environment tend to rely more on spatial configuration than people who are familiar with environment in developing cognitive maps of the environment. Nevertheless, when people gradually become familiar with a new environment, which means the increase of their associativity (personal experiences) with the new environment, the association between cognitive representation and spatial configuration of the urban environment gradually decreases. That may be the reason why the association between cognitive representations and spatial configuration of the urban environment for residents is smaller than students as newcomers. However, global integration is still the only variable predicting the variance in landmark scores and local integration and connectivity are the two variables explaining the variance in path scores both for familiar (residents) and unfamiliar (students) people.

Overall, these findings indicated that as people experience the environment for a period of time, besides space configuration, some additional factors such as familiarity, commutativity, travel mode, and location of home, and so on, may play a role in developing knowledge of the urban environment.
6.1.5 Discussion --- The Role of Syntactical Measures in Spatial Cognition

In this section, the role of syntactical measure (i.e., global integration, local integration, connectivity, and intelligibility) in spatial cognition will be discussed respectively based on the findings previously summarized.

**Global Integration**  The results from the relationship and experimental studies indicated that global integration (i.e., global accessibility) is an independent variable predicting the variance in landmark scores for both residents and students. Higher global integration results in higher landmark scores in residents’ and students’ landmark recognition. However, the results showed that global integration does not predict the variation in path scores for both residents and students. When the results were compared between residents and students, it was found that the predictive power of global integration on landmark scores is higher for students as an unfamiliar group than for residents as a familiar group.

A positive relationship between global integration and landmark scores was also found for residents in the relationship study when intelligibility was considered in the regression model. Again, global integration did not play a role in path recognition. Moreover, when the multiple regression analysis was conducted separately for each neighborhood for residents, the same pattern was found. This was consistent with the results discussed above.

The experimental study found that global integration also plays a role in students’ scene recognition. With a decrease in global integration values, the percentage of correctly and partially correctly recognized scenes decreases as well.

Overall, the findings discussed above strongly indicated that global integration plays a significant role in individuals’ landmark recognition, even more so for individuals unfamiliar
with the environment. In general, people tend to recognize landmark buildings along streets that have high global syntactical accessibility whereas buildings along streets with low global accessibility are not remembered. However, the study findings suggest that global integration is not important in developing path knowledge.

Local Syntactical Measures The results of the relationship study and the experimental study showed that local syntactical measures (local integration and connectivity) are the two independent variables explaining the variation in path scores for both residents and students. This means that higher local integration and higher connectivity result in higher path scores (i.e., higher path recognition). However, the results showed that local syntactical measures do not play a role in predicting landmark scores for both residents and students. When the results were compared between residents as a familiar group and students as an unfamiliar group, it was found that the predictive power of local syntactical measures on path scores is higher for students than for residents.

A positive relationship between path scores and local syntactical measures was also found for residents in the relationship study when intelligibility was included in the regression model. However, no significant relationships were found between landmark scores and local syntactical measures. When the multiple regression analysis was performed separately for each neighborhood for residents, the same pattern was found (i.e., findings were consistent with the patterns found in the relationship and experimental studies).

Overall, the findings discussed above strongly indicated that people’s path knowledge is built more based on accessibility within the immediate environment, not the whole layout of the urban environment. This is even more prevalent for individuals who are unfamiliar with the environment. However, local syntactical measures are not important in developing
Intelligibility  The results of experimental study showed that intelligibility plays an important role in students' path recognition. It was found that overall, higher intelligibility results in higher path scores. Students in a high intelligible neighborhood drew more accurate paths in the sketch maps than those in a low intelligible neighborhood. On the other hand, the results from the experimental study indicated that intelligibility does not play a role in students' landmark recognition. The difference in mean accuracy of landmark's scores for the students between the two neighborhoods is not significant. A similar pattern was also found in the comparative analysis (causal comparative study) of the accuracy of cognitive representations for residents between the two neighborhoods.

However, the results of the multiple regression analysis in the relationship study for residents indicated that intelligibility is negatively associated with both residents' landmark and path recognition when intelligibility was included in the model. Based on this, higher intelligibility results in lower landmark and lower path scores. These results seem inconsistent with the results from the experimental studies. The first reason may be attributed to the different unit of analysis used in these studies. In the experimental and causal-comparative studies, the unit of analysis was the individual (student or resident). However, the unit of analysis in the relationship study was the element of the urban environment (building or path). Second, only two intelligibility values were included in the regression model, which results in a lack of variability in terms of the range of intelligibility (from 0 to 1). Third, the other syntactical measures (i.e., besides intelligibility) were also included in the regression model. Thus, these potential factors may have produced the inconsistency of the study findings between them.

Experimental and causal-comparative research designs are stronger in uncovering the
causal relationships than a relationship study (Groat and Wang, 2002). Therefore, in spite of the inconsistence, it is appropriate to conclude that intelligibility plays an important role in path recognition (i.e., higher intelligibility results in higher accuracy of path recognition), while it does not affect people’s landmark recognition. The question then becomes, why does intelligibility only affect people’s path recognition? The answer will come from understanding the meaning of intelligibility. Intelligibility focuses on describing the characteristics of spatial configuration (i.e., street network), not the characteristics of buildings. High intelligibility means an individual can easily and accurately understand the overall structure of the urban environment based on the local environment he/she travels. Thus, it effects the development of path knowledge.

In addition, the results from the experimental study showed that intelligibility affects students’ scene recognition and perceptions of spatial cognition ability related to the new environment. Students (as the unfamiliar group) in a more intelligible neighborhood were able to correctly recognize more scenes, felt that it was easier to draw the sketch maps, had more confidence in their sketch map drawings, and had more confidence in scene recognition than those in a less intelligible neighborhood.

Overall, these findings indicated that intelligibility plays an important and positive role in cognitive representations and legibility of the urban environment.

**6.2 LIMITATIONS OF THE STUDY**

There are two methodological limitations in this study. The first methodological limitation relates to the sampling strategy and the second relates to the generalization of study findings.
In this study, convenience sampling was adopted to select residents in the correlational study because the sampling frame in the study area couldn’t be obtained. Therefore, the spatial cognition pattern obtained from the homogeneous group, age from 20 to 30 years old, could not be generalized to the all age population. On the other hand, for the two neighborhoods together, a total of 70 residents rejected the interviews because they did not have time to participate in the study. Thus, the response rate was 48%. For residents who rejected the interviews, their age (based on observation) and gender were recoded. A T-test revealed that the age and gender differences between the two neighborhoods for residents who rejected the interviews are not statistically significant in this study. However, this limitation, to a certain degree, was addressed by the student samples in the experimental study, in which match and randomization were used to form the experimental group.

The second limitation is related to generalization of the study findings. Only one middle size city in China was selected for this study since middle size cities comprise 62% of the cities in China. In this regard, the results of this study cannot be generalized to the other sizes of cities, such as big cities (metropolitan cities) and small cities. However, this study may provide some insights on Eastern Asian cities that have similar characteristics with the study area: a high-density land use pattern with a high density of population and mixed-use neighborhoods within walking distance. On the other hand, a comparative analysis (comparing absolute values of bivariate correlations and multiple regression coefficients) was conducted to investigate the differences in cognitive representations between residents as a familiar group and students as an unfamiliar group. However, strictly saying, the findings from the two different groups were not comparable since participants were selected from different sampling frames and were based on results of different research strategies. Likewise, individual and socio-economic differences may affect validity of comparison between the two groups. Statistical significance tests (parametric and non-parametric tests) showed that resident and student samples are comparable in gender (p<0.01) but not
comparable in age. In addition, it is expected that the student participants are more educated, more intelligent, and also have better spatial abilities (on average they are younger, see Anderson, 1995) than the residents. Thus, the comparison of spatial cognition between familiar and un-familiar people is exploratory in nature and the findings regarding the role of familiarity in spatial cognition are only suggestive.
CHAPTER 7: CONTRIBUTIONS TO THE FIELD OF URBAN DESIGN

This study primarily contributes to the body of knowledge in the field of urban design, which has the potential to inform urban design practice. As such, there are two major audiences that will benefit from the findings of the study: researchers studying spatial cognition, wayfinding, and orientation at the urban scale and urban design practitioners and policymakers in urban planning departments. In this chapter, the main contributions to the body of urban design knowledge, implications for future research, and implications for urban design practice will be presented.

7.1 CONTRIBUTIONS TO THE BODY OF URBAN DESIGN KNOWLEDGE

Previous literature has identified that many researchers argued that spatial configuration of the urban environment is a primary root for people when shaping their cognitive maps. The relationships between the physical elements of the urban environment are the fundamental root by which humans recognize a built environment. After that, more detailed cognitive maps can be developed (Lynch, 1984; Appleyard, 1976; Evans, 1980; Passini, 1984; Kim, 2001). In addition, Lynch (1990) also emphasized the importance of spatial configuration, such as hierarchies, arrangement of paths, and location of landmarks, in shaping the legibility of the urban environment.

On the other hand, recent development in Space Syntax theory and methodology offer researchers an opportunity to objectively describe the spatial configuration of the environment. Hillier (1988, 1996) argued that intelligibility, as measured by Space Syntax, is assumed to describe the characteristics of spatial configuration. High intelligibility means
individuals can easily acquire the overall structure of the layout based on the immediate environment that they experience within the layout.

However, the arguments mentioned above were grounded more on the results of qualitative or quantitative studies at the building scale. Only one empirical study (Kim, 2001) that was conducted in the urban environment supported some of arguments above. Kim’s study focuses more on exploring the relationships between one of the physical elements (i.e., paths) and spatial configuration. The results of his study indicated that path frequency in residents’ sketch maps has strong correlations with local integration and global integration.

This study confirmed some of the previous arguments and expanded our understanding of how spatial configuration of the urban environment relates to spatial cognition. In particular, the study found the followings:

a) For residents, landmarks have strong correlations with global integration and local integration. For students, landmarks have strong correlations with the three syntactical measures (i.e., global integration, local integration, and connectivity). However, the results of multiple regression analysis indicate that for both residents and students, global integration is the only significant variable explaining the variation in landmark scores. The findings indicate that people tend to remember and recognize buildings along streets that have higher global syntactical accessibility than those buildings along streets with low global syntactical accessibility. Overall global syntactical accessibility within a layout is more important to an individual’s landmark recognition than local syntactical accessibility.

b) For both residents and students, paths have strong correlations with global integration, local integration, and connectivity. However, the results of regression analysis showed that the local syntactical measures (i.e., local integration and connectivity) are the two significant
variables explaining the variation in path scores. The findings suggest that people tend to remember and recognize streets that have higher local syntactical accessibility than those having low local syntactical accessibility. Although there is correlation between global syntactical accessibility and path scores, global syntactical accessibility does not predict path scores, i.e., does not play a role in path recognition.

c) The results of the experimental study indicate that accuracy of path recognition, correctness of scene recognition, and major indicators of spatial cognition ability in post-experimental interviews are higher for people in a more intelligible neighborhood than those in a less intelligible neighborhood. However, no differences in landmark recognition were found between more intelligible and less intelligible neighborhoods. Overall, the findings suggest that intelligibility has an effect on perceived legibility, i.e., higher intelligibility of the environment results in higher perceived legibility. In general, individuals tend to shape a more accurate cognitive map, in particular as it relates to paths, in a more intelligible neighborhood than in a less intelligible one.

d) The results of the comparative analysis between residents as a familiar group and students as an unfamiliar group reveal that the correlations (r) and coefficients of determination (R²) between cognitive representations (i.e., landmarks and paths) and three syntactical measures (i.e., global integration, local integration, and connectivity) for unfamiliar group are higher than those for the familiar group. The findings show that syntactical accessibility within the immediate environment is more important for a newcomer’s path recognition than for a familiar person’s path recognition. Whereas, global syntactical accessibility within a layout plays more important role in a newcomer’s landmark recognition than in a familiar person’s landmark recognition. Overall, the findings suggest that newcomers rely more on spatial configuration in developing cognitive maps than those who are familiar with the environment.
7.1.1 Implications for Future Research

Based on Lynch (1960) there are a total of five urban elements in human cognitive maps, i.e., landmarks, paths, districts, nodes, and edges. In this study, only relationships between two of these five cognitive representations (i.e. landmarks and paths) and spatial configuration have been examined. The literature review (Table 1) indicated that the other three cognitive representations, particularly nodes and districts, are also important elements for human wayfinding and orientation in the cities. Their relationships with spatial configuration of the urban environment, as measured by Space Syntax, needs to be further explored in the future.

Besides using axial lines to measure the spatial configuration of the urban environment, another way to represent urban spaces is by using Space Syntax to measure the visibility (isovists) of the urban space. It will be also interesting to investigate the relationships between those cognitive representations and visibility of the spaces in the urban environment.

Two neighborhoods were selected as study areas in this study. The syntactical measures in these two neighborhoods were calculated based on the whole city street network. It will be interesting to see if the findings of this study will be confirmed if the syntactical measures are calculated by taking into account only street layout of the neighborhood, i.e., consider neighborhoods as self contained systems. On the other hand, there are many types of medium size districts within the city, such as commercial and business districts, downtown areas, and so on. It will be useful to explore how individuals shape their spatial cognition when traveling through such diverse areas.
The main purpose of the study focuses on human spatial cognition in the urban environment, not the wayfinding performance. However, further studies need to be performed to investigate how people orient and find their way in complex urban environments based on different spatial cognition patterns, since the literature review indicated that little research has been conducted in those fields.

7.2 IMPLICATIONS FOR URBAN DESIGN PRACTICE

It is known that a legible environment contributes to an individual’s orientation and wayfinding (Lynch, 1984; Rapoport, 1987). Nowadays, with rapid urbanization and mass development in cities, the urban environment becomes more and more complex. In this regard, designing a legible environment is an important issue that has been included in the sustainable design guidance (Ewing and Clemente, 2005; Battle and McCathy, 2001). Thus, understanding the characteristics of the urban environment that contribute to legibility is very important, particularly for newcomers, and has potential to inform the future of urban design and planning for a better living and working environment (Nasar, 1994).

There is a strong potential that the findings of this study will contribute to the urban design practice since the independent variables (i.e., spatial configuration and related syntactical measures) could be manipulated/controlled by urban designers during the design stage (Kuo, 2002).

An important finding of the study is a demonstrated strong positive association between cognitive representations and syntactical properties of the spaces. In particular, the study showed that global syntactical accessibility within a neighborhood layout is important for landmark recognition. This finding could assist planners/designers/policymakers in developing a vocabulary of urban attributes. They could arrange landmark buildings in
congruence with the hierarchal structure of the spatial configuration, as measured by Space Syntax, and coordinate them with the natural way that humans recognize urban environments. For example, it might be useful to locate buildings envisioned to become landmarks in the neighborhood (such as a church, community center, shopping center, and so on) along streets that have higher global syntactical accessibility. This can ensure that such buildings will leave strong impressions in people’s minds and be identified as landmark buildings. From another point of view, for some buildings located along the streets that have low global syntactical accessibility, if we want them to be easily identified and leave a strong impression in people’s minds, it will be useful to improve the distinctiveness of the buildings against their background (i.e., color etc.), or improve and add wayfinding signage system.

On the other hand, the study indicates that accessibility within the immediate environment is important to path recognition. People tend to recognize more streets with high local syntactical measures (local integration and connectivity) than those streets with low local syntactical measures. Based on it, it will be helpful to pay more attention to streetscapes, sidewalks, and pavements in streets that have high local accessibility and high connectivity to neighboring streets. Thus, such streets will further contribute to developing strong impressions in people’s minds. This is particularly so for the important streets in the districts that attract a lot of “first time” visitors, since a stronger associate is found between path scores and local syntactical measures for students as an unfamiliar group than residents as a familiar group.

Literature has also shown that after Lynch (1960), researchers in environmental cognition have always searched for effective approaches to measure the legibility of the urban environment. One indirect method has been measuring wayfinding performance, which is the outcome of legibility of an environment on human spatial cognition. Another has been measuring the accuracy of sketch maps of the built environment or correctness of
recognizing the pictures of the environment in a simulated or natural setting. However, these two indirect methods for measuring legibility are inconvenient and time-consuming, especially for the design practice and decision-making. More recently, one study has attempted to objectively measure the imageability of the urban environment. However, the measure has low reliability (Ewing and Clemente, 2005).

To fill the gap in this field, this study focuses on establishing a connection between subjective and objective evaluations of the urban environment. The findings of this research study showed that for students, higher intelligibility of the neighborhood (i.e., an objective characteristic of spatial configuration) results in more accurate path recognition and better scene recognition (i.e., higher perceived legibility). However, there is no difference in accuracy of landmark recognition between the high intelligible neighborhood and low intelligible neighborhood. Similar results are also found for residents. The literature review indicated that Space Syntax methodology has been utilized in the urban design practice to understand and predict human movement (Cowan, 2002; Battle and McCarthy, 2001). The findings of this study suggest that the Space Syntax methodology could be used by urban designers and policymakers in understanding and manipulating one aspect of environment, i.e., spatial configuration, that contributes to improved legibility.

From this point of view, it will be useful to pay more attention to the intelligibility of the urban environment. Thus, another question may be asked --- how do urban designers and policymakers increase the intelligibility of a neighborhood? The association between global and local accessibility of a neighborhood layout defines intelligibility (Hillier, 1996). Thus, it might be useful to design streets that include both high connectivity with the immediate streets and overall high accessibility to all the other streets within a layout. An effective way to achieve this is to increase the street’s connections to its neighboring streets, as well as to the integration core in the neighborhood. This is relevant for newly designed environments.
but also for existing city structures, which could be improved following the principles outlined above.

It is important to state that legibility is only one aspect of urban design quality. Sometimes, people prefer a kind of mysterious, complex, or even maze-like urban environment to get exploratory pleasures and surprises (Kaplan and Kaplan, 1982). Thus, designing an urban environment is more providing a balance between legibility & coherence and mystery & complexity in the environment.

Main design implications of the findings of this study discussed above could be summarized as the following:

1) Global syntactical accessibility is important to individuals’ landmark recognition. People tend to recognize more buildings along streets with high global accessibility within a layout than those buildings along streets with low global accessibility. This is even stronger for newcomers than for residents. Based on this, it is suggested to locate buildings that are envisioned to become landmarks in a district, i.e., neighborhood, city center, etc., along streets that have high overall accessibility within the layout.

2) Local syntactical accessibility is important to individuals’ path recognition. People tend to recognize more streets with high local syntactical measures than those streets with low local syntactical measures. This is even more for newcomers. Thus, it is suggested to pay particular attention to streetscapes, sidewalks, and pavements in streets that have high local accessibility and high connectivity to the neighboring streets.

3) The study found that for newcomers (individuals unfamiliar with the environment), higher intelligibility of the neighborhood results in more accurate path recognition and better scene recognition (i.e., better perceived legibility). For residents, it was also found that high intelligibility results in greater accuracy of path recognition. All these suggest that increasing the intelligibility of the neighborhood will contribute to improved legibility of the
urban environment. The effective way of increasing the intelligibility of the environment is by increasing streets' connections to their neighboring streets as well as to the integration core of the district.
Bibliography


Appendices
Appendix 1: Sketch Maps for Residents

Please draw the sketch maps of the neighborhood of Dong-pai-lou in which you are living, including important buildings and roads. If you remember, please write down their names.
Please draw the sketch maps of the neighborhood of Rong-wan-zhen in which you are living, including important buildings and roads. If you remember, please write down their names.

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- Xiang River
- Bridge Ju-zhi-zhou
- Ju-zhi-zhou
- Yuelu Mountain
Appendix 2: Semi-structured Interview Form

Based on what you have drawn in the paper, now I will ask you some additional questions. Thanks for your participation.

1. Why do you remember and draw certain roads in the sketch map rather than the others?

2. Why do you remember and draw certain buildings in the sketch map rather than the others?

3. What are the features of the roads that you have drawn in the paper, which make them unforgettable in your mind?
3. What are the features of the buildings that you have drawn in the paper, which make them unforgettable in your mind?

Landmark 1:

Landmark 2:

Landmark 3:

4. How old are you? ____________ years

5. How long have you lived in Dong-pai-lou neighborhood? ____________ years

6. The respondent is:   Male ________     Female ________
Appendix 3: Protocols for Measuring Building Characteristics

Distinctiveness: the degree of contrast of a building’s color, mass and height to its background. An ordinal scale from high, medium, and low based on the degree of contrast is encoded as the scores of “3”, “2” and “1”.

Historical meaning: the historical meaning of a building is determined by its history and building form. If the building has a long history with a distinctive Chinese traditional facade, it is encoded as “3”. If the building has a relatively short history, but having a Chinese traditional facade, it is encoded as “2”. If the building is built up in the form of modern architecture other than Chinese traditional form, it is encoded as “1”.

Function: The function of a building is determined by its actual building use. They are treated as an ordinal scale to reflect the complexity of the functions of the building. If a building has mixed uses, it is encoded as “3”. If a building has commercial or retail uses, it is encoded as “2”. If building use is a single function other than commercial or retails, such as residential or governmental uses, it is encoded as “1”.

Maintenance: maintenance is determined by a building’s degree of cleanness, neatness and conservation of the facade. An ordinal scale from high, medium and low is assigned to maintenance measurement as “3”, “2” and “1”.
Appendix 4: Spatial Ability Tests --- Paper Folding Tests

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below. (In this problem only one hole was punched in the folded paper.)

![Sample Problem Diagram]

The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.

In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the answer is the figure that shows the positions of the holes when the paper is completely unfolded.

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.
Part 1 (3 minutes)

1

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A B C D E

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Part 2 (3 minutes)

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Appendix 5: Sketch Maps for Students

Based on your memory of Dong-pai-lou neighborhood you have traveled, please draw the sketch map of the neighborhood, including important buildings and roads.
Based on your memory of Rong-wan-zhen neighborhood you have traveled.

Please draw the sketch map of the neighborhood, including important buildings and roads.
Based on your memory, please locate each picture (the number below each picture) correctly on the real map of Dong-pai-lou neighborhood as many as possible you can.

ID:_________
Based on your memory, please locate each picture (the number below each picture) correctly on the real map of Rong-wan-zhen as many as possible you can.

ID_________
Appendix 7: Scenes for Recognition Tests --- the Dong-pai-lou Neighborhood

Scenes along Streets with High Global Integration:

Scenes along Streets with Medium Global Integration:
Scenes along Streets with Low Global Integration:
Scenes Outside the Neighborhood:
Scenes for Recognition Tests --- the Rong-wan-zhen Neighborhood

Scenes along Streets with High Global Integration:

Scenes along Streets with Medium Global Integration:
Scenes along Streets with Low Global Integration:
Scenes Outside the Neighborhood:
Appendix 8: Post-experimental Interview Form

Thanks for your participation, next I will ask you several additional questions.

1. How easy or difficult was to draw the sketch map of the neighborhood based on the previous traveling experience?
   - Very easy
   - Easy
   - Fair
   - Difficult
   - Very difficult

2. How confident you are about the accuracy of the neighborhood sketch map you just have drawn?
   - Quite Confident
   - Confident
   - Fair
   - Not sure
   - Not at all

3. How confident you are with the location of the scenes/photographs you have located in the map of recognition tests?
   - Quite Confident
   - Confident
   - Fair
   - Not sure
   - Not at all

4. Do you think you are able to direct a stranger to the destinations/roads in the neighborhood?
   - Yes
   - Fair
   - No

5. How confident would you be of the directions you’d give to such as a stranger?
   - Quite Confident
   - Confident
   - Fair
   - Not sure
   - Not at all

____________________________________
Respondent’s gender
   - Male
   - Female

Respondent’s age _____________ years

Respondent’s major _______________
Appendix 9: Data Analysis Sheet for Landmarks and Paths for Residents
(Sketch Maps)

Landmark Buildings (Unit of analysis: building)

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Note:
N: neighborhood; D: Dong-pai-lou; R: Rong-wan-zhen; I: intelligibility; Dist: distinctiveness; His_m: historical meaning; Fun: function; Maint: maintenance

Paths (Unit of analysis: street)
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Note:
N: neighborhood; D: Dong-pai-lou; R: Rong-wan-zhen; l: intelligibility; Dist: distinctiveness; His_m: historical meaning; Fun: function; Maint: maintenance; Score_recoded: recode the scores for ignoring labeling situation
## Appendix 10: Data Analysis Sheet for Landmarks and Paths for Students (Sketch Maps)

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Note:
N: neighborhood; D: Dong-pai-lou; R: Rong-wan-zhen; Dist: distinctiveness; His_m: historical meaning; Fun: function; Maint: maintenance; Score_recoded: recode the scores for ignoring labeling situation
## Appendix 11: Data Analysis Sheet for Recognition Tests and Post-experimental Interviews for Students

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<td>2.0</td>
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<td>2.0</td>
</tr>
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</table>

The range of score is from 24 to 0 for each respondent (recognition tests)

The range of score for each question is from –4 to 4 (post-experimental interviews)

Q1: Easiness of drawing sketch maps
Q2: Confidence of sketch maps
Q3: Confidence of recognition tests
Q4: Capability of giving direction to strangers
Q5: Confidence of giving direction to strangers

Note:

Total Rec_Score: total scores of correctness of picture recognition
Rec_High: number of scenes recognized correctly along high integration road
Rec_Med: number of scenes recognized correctly along medium integration road
Rec_Low: number of scenes recognized correctly along low integration road
Rec_Wrong: number of scenes outside the neighborhoods that respondent wrongly thinks they are within the neighborhoods